THE UNIVERSITY OF ALBERTA

AN EXAMINATION OF RECOVERY OF RESOURCES FROM SOLID WASTES IN THE CITY OF EDMONTON

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF BUSINESS ADMINISTRATION

FACULTY OF BUSINESS ADMINISTRATION AND COMMERCE

EDMONTON, ALBERTA

SPRING, 1977

ABSTRACT

The initial objective of this study was to review the present method of handling of residential solid waste in the City of Edmonton, and the composition of the material. Thus a survey was conducted of typical examples of the "state of the art" in the field of resource recovery, primarily in North America. This included a study of systems designed for:

(i) Recovery of the energy contained in the refuse for power generation, or for heating and cooling systems.

(ii) Recovery of one or more of the materials contained in the refuse as collected in the municipal system.

(iii) Combined recovery, which removes the most advantageous of the materials before combustion of the residue for its energy content.

(iv) Pyrolysis, which is the thermal decomposition of the refuse to produce a fuel and, possibly, some recovered materials.

(v) Source separation, which is the recovery of desirable materials at the point of generation before they enter the solid waste disposal system.

(vi) Methane recovery at the point of final disposal.

A review was conducted of the market situation in Edmonton for the potentially recoverable material and energy components to determine what incentives exist for recovery. The final objective was to develop recommendations which would be of benefit in determining a future course of action for the City of Edmonton in the field of resource recovery.

The general conclusion which resulted from the study was that full-scale resource recovery in any of its presently developed forms is not economically justifiable. However, it was recommended that some limited aspects of recovery of paper and metal should be pursued at the present time, and that methane and energy recovery should be re-examined at a later time as economic conditions change.

ACKNOWLEDGEMENTS

The writer extends sincere thanks to Dr. M.J. Dunn for his constructive advice and guidance throughout over two years of thesis research. As well, sincere thanks are extended to Dr. S. Brown and Prof. P. Bouthillier, who have provided much timely assistance.

The writer's employment with Edmonton Water and Sanitation involves him in the field of solid wastes, and in this capacity resource recovery is a matter of continuing interest. This has given him the opportunity to meet with many individuals with similar interests, and to attend workshops and seminars pertaining to this field. His thanks go to the management of the City of Edmonton for these opportunities.

Mrs. M. Williams and her staff have been very helpful in typing several drafts of this thesis over a two year period and deserve special recognition for their assistance and patience.

Last, but not least, to my wife Avis and our children, Bruce, Grant and Carol, goes my heartfelt appreciation. Their patience and understanding in putting up with my preoccupation with this thesis over an extended period of time has been a source of great comfort to me.

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CHAPTER I

INTRODUCTION

Considerable interest is currently being expressed in the field of resource recovery from solid wastes, in the news media as well as the political and private forum. As illustrated in this thesis, there are a large and varied number of systems and processes being used for resource recovery, in different parts of the world. In general, the systems can be roughly categorized into:

(a) Systems for the recovery and beneficial use of the energy contained in the solid wastes.

(b) Systems for the recovery in their original form of the reusable components of the solid waste stream. The separation into components can take place either at

    (i) A central plant where a mixed stream of solid wastes is separated out into components. The separated products are then absorbed into the secondary materials markets, or

    (ii) Individual homes, where the householder separates and packages his waste materials in various categories before putting them out for collection. The different categories must then be collected separately.

(c) Combinations of the previous systems, where the most economically attractive materials are salvaged for re-use in their original form, the remainder is used

for the generation of energy, and the non-combustible residue is landfilled.

The options in solid waste management are pictured in Figure 1[1]. This figure illustrates the number of decision points in solid waste management, and highlights the inter-relationships between the various disposal alternatives. The decision as to whether resource recovery will be utilized and of what process is to be used depends on a number of factors including the cost and availability of alternative means of disposal, the availability of and distance from markets for the products, and even the social norms of the community.

It has been estimated that the United States disposes of 130 million tons of refuse per year[2]. The energy content of this refuse, equal to 150 million barrels of petroleum, would have a value of $1.5 billion. The 12 million tons of metal and 12 million tons of glass has a value of $1 billion. Combined with a present disposal cost of $1 billion, the potential value of the refuse is $3.5 billion. The Canadian figures would be approximately 10% of the U.S. data[3].

In order to ensure the success of a resource recovery project there are four conditions which must be met. If any one of the four is not met, then the chance of success of the project is significantly lessened. As stated by Edward L. Titlow, the four conditions are:

(a) The community must have a problem: that is, landfill areas have or shortly will be depleted, cover materials may be scarce, leachate from the landfill is a cause of ground water pollution, or perhaps governmental

SOLID WASTE MANAGEMENT DECISION ALTERNATIVES

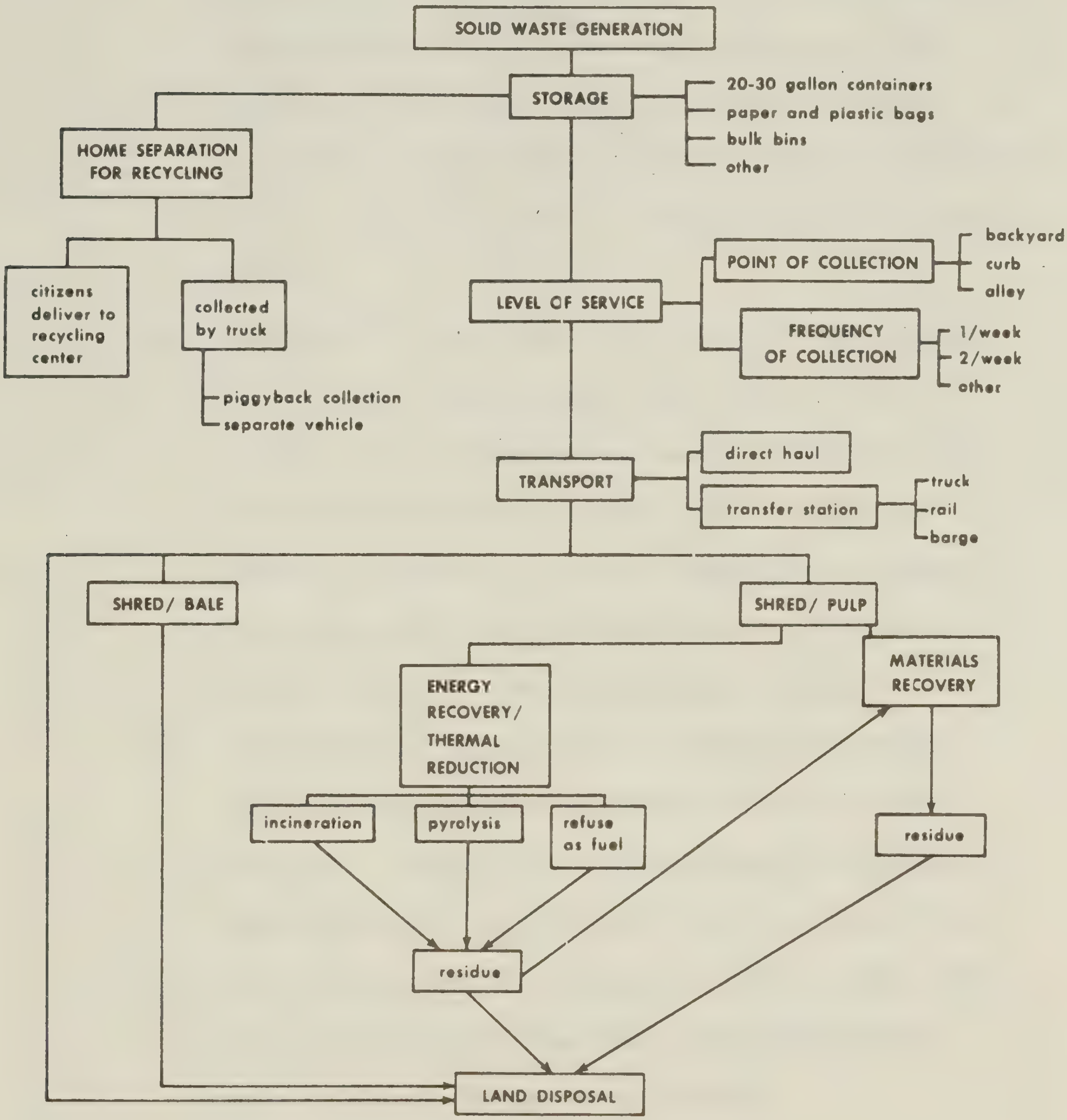


FIGURE 1

SOURCE: U.S.E.P.A., DECISION MAKERS GUIDE

agencies consider the present landfill practice to be unsanitary. Alternate landfill areas may be too remote. Any or all of these will result in a disposal cost per ton unacceptable to the community. However, refuse disposal in a sanitary landfill is still the most economical method provided a long term area is available, and this is true in spite of popular emphasis on resource recovery.

(b) Leadership for implementation of a solid waste energy and resource recovery project must come from the community and an organization must be created to deal with refuse disposal problems. This "institution" should be prepared to face the complexities presented by the necessities of joining together public and private sectors - a unique marriage, indeed.

(c) Some means must be provided to finance the project, such as industrial revenue bonds, pollution control bonds, etc. Security for the bonds may be provided by plant revenues or by the State. At the present time, there are very few firms able to finance a solid waste project with private funds due to the high cost of money. This may change in the future.

(d) A market must be determined for the produced energy, and the available market determines the type of process to be selected. Markets for recovered products must

> also be identified, but the energy market is of prime importance due to the large volume of organic energy source material compared to the lesser quantity of recovered metals and glass[4].

In evaluating resource recovery, it is important to remember that solid waste is still a problem to be disposed of, not a miraculous new source of inexpensive materials or energy. Resource recovery should only be practiced where a thorough analysis of all the costs, including the social, proves that that is the most appropriate method of solid waste disposal.

FOOTNOTES

CHAPTER I - INTRODUCTION

[1]U.S., Environmental Protection Agency, Decision Makers Guide in Solid Waste Management, (1976), p. IX

[2]Helmut W. Schulz, "Cost/Benefits of Solid Waste Reuse", Environmental Science and Technology, IX, No. 5 (May, 1975), p. 423

[3]Author's Estimate, based on population comparisons

[4]Edward L. Titlow, "What Every Public Official Should Know About Resource Recovery", Solid Waste Systems, IV, No. 6 (December, 1975), p. 20

CHAPTER II

THE EDMONTON SOLID WASTE SYSTEM

BACKGROUND INFORMATION

The City of Edmonton provides a residential refuse collection service for approximately 460,000 people. About 26% of this number (120,000 people) are serviced through one of two private collection contractors working under sub-contract to the City. The contract area in the West End, consisting of 65,000 people, is presently served by Gateway Disposal Ltd., a small Edmonton firm. The South Side contract area consists of 55,000 people and is served by B.F.I. Waste Systems Division, a subsidiary of a major U.S. solid waste contractor.

City forces provide the collection service for the remaining 340,000 people in the City. In addition to the residential collection, the City provides a trade waste collection service. Business firms prepared to use standard garbage cans for storage of refuse can arrange for collection for a fee set at a level designed to return the actual cost of providing service. Under the terms of the Garbage Bylaw 3942, apartment developments receive one free collection per week, provided that they are prepared to use standard garbage cans located adjacent to the City street. Where more than one collection per week is desired, the additional collections are charged at the actual cost of providing service. The City forces are not equipped to collect from bulk containers, so that businesses and apartments wishing to save space by the use of bulk containers rather than standard garbage cans must arrange for collection by commercial

contractors. The City currently has trade waste collection contracts with approximately 1400 customer firms.

In 1975, 140,884 tons of refuse, including the amount handled by the sub-contractors, were collected from residential and City trade waste collections. This material was all disposed of in four landfills, three City-owned and one privately owned. The City-owned South Side Landfill closed in April, 1975 and was replaced later in the year by the Clover Bar Landfill. The Frontier Landfill continued in operation, accepting the bulk of the residential refuse. The privately owned B.A.C.M. site is the only landfill on the West Side of the City. There were 877,252[1] tons of material deposited in the landfills in 1975, including the residential refuse, commercial and industrial refuse, dirt, rubble, refuse hauled by private citizens, and some liquids.

To reduce the total distance travelled by the City operated collection vehicles, the City is currently operating two transfer stations and has one more in the planning stage. Under the transfer concept, stations are located at various points throughout the City, and the collection vehicles travel only the relatively short distance from their collection point to the nearest transfer station, where they deposit their refuse. Thus, instead of spending long periods of time travelling to remote disposal points, they can return quickly to their prime task, which is that of collecting garbage. At the transfer station the refuse is densified and transferred into large capacity, long haul trailers for transportation to the disposal site.

The densification process used by the City of Edmonton is by shredding.

In the shredding process the garbage is run through a type of grinder, which breaks it up into relatively small pieces. Paper and plastic sheets are cut into small pieces, glass is pulverized and the metal cans are crumpled into small balls. As a result of the densification one driver, with a semi-trailer truck, can make the long haul to the disposal point carrying the same amount of garbage as ten to fifteen collection vehicles. Table 1[2] shows an economic comparison between the total cost of collection and disposal by hauling direct to the landfill versus the total cost of collection and disposal by hauling with collection vehicles to a transfer station and then by long haul vehicles to the final disposal point. In 1973 dollars the cost by transfer is $1.42 per ton less than the cost of hauling to the landfill with collection vehicles. The most common collection vehicle used by the City of Edmonton is the one man, twelve cubic yard Haul-All vehicle (See Figure 2). A comprehensive evaluation of various vehicle types under City of Edmonton conditions was performed from 1970 to 1973 inclusive. This evaluation showed that the Haul-All collection vehicle was the most efficient available, up to a distance of approximately 15 miles round trip to the disposal point (See Figure 3). Although this vehicle has not yet gained wide acceptance in the collection industry, it has definitely proven its worth in the City of Edmonton service. The gradual introduction of the Haul-All collection vehicle has enabled City forces to increase their productivity from 940 tons per man per year in 1970, to 1,404 tons per man per year in 1976.

TABLE 1

COMPARISON OF DIRECT LANDFILL DISPOSAL
FOR THE CITY OF EDMONTON
WITH DISPOSAL THROUGH TRANSFER STATIONS

TOTAL COST OF COLLECTION
AND DISPOSAL HAULING DIRECT
TO CLOVER BAR LANDFILL

AREA	1973 TONNAGE	COLLECT	HAUL	DISPOSE	TOTAL COST	TOTAL COST/TON
West	31,686	263,600	184,300	26,000	473,900	$14.96
South	28,876	238,500	211,000	23,700	473,200	16.39
North	32,645	208,600	223,300	26,800	458,700	14.05
TOTAL	93,207	710,700	802,900	76,500	1,405,800	15.08

TOTAL COST OF COLLECTION
AND DISPOSAL USING HAUL-ALLS
AND TRANSFER TO CLOVER BAR
LANDFILL

AREA	1973 TONNAGE	COLLECT	SHORT HAUL	TRANSFER & HAUL TO LANDFILL	DISPOSE	TOTAL COST	TOTAL COST/TON
West	31,686	162,200	68,200	151,700	26,000	408,100	$12.88
South	28,876	157,500	84,400	164,900	23,700	430,500	14.91
North	32,645	178,100	61,400	168,000	26,800	434,300	13.30
TOTAL	93,207	497,800	214,000	484,600	76,500	1,272,900	13.66

SOURCE: E.W. & S., Solid Waste Report

HAUL-ALL COLLECTION UNITS

FIGURE 2

COLLECTION VEHICLE COST COMPARISON
EDMONTON, 1973

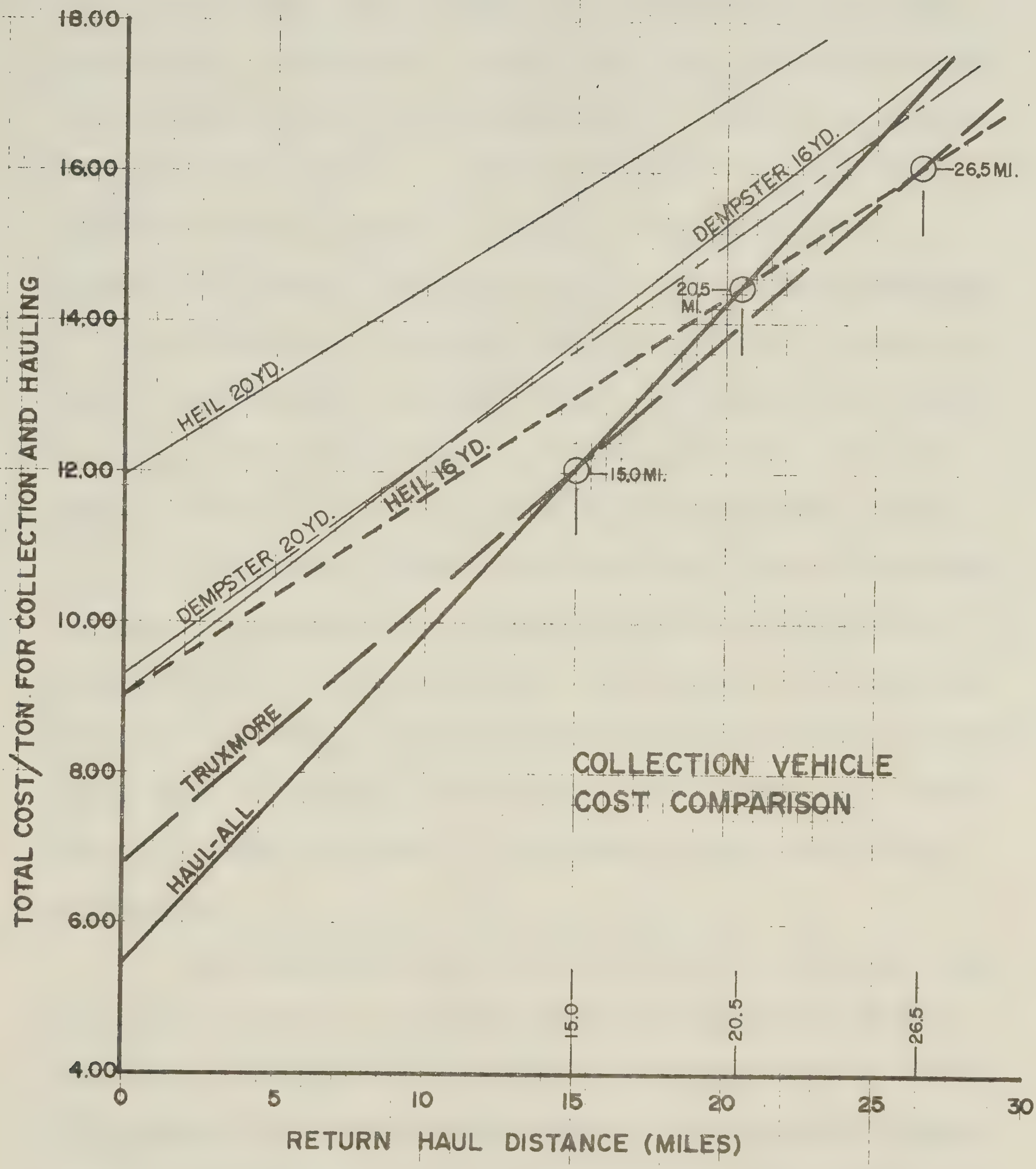


FIGURE 3

SOURCE: E.W. & S., SOLID WASTE REPORT

COMPOSITION OF SOLID WASTE

Solid waste is an extremely heterogeneous material, with the composition varying widely from one time of year to another and also from one truck load to another on any given day of the year. As an example, the quantity of grass in the waste stream will range from zero in the winter time in the Edmonton climate to as high as 40% in the early summer. In addition, there will be significant variations from one community to another, varying with size of building lot, economic standards, and life style. These variations in the concentrations of various components will have a significant impact on any materials recovery process. In addition, as a result of the variations in components, the heat content will also vary widely. This will have an effect on any energy recovery process.

In order to provide a meaningful base of data in Edmonton, a program of sampling of the shredded refuse from the Coronation Transfer Station has been conducted. The results[3] of the sampling program for the first 6 months of 1976 are as shown in Table 2. The figures show considerable fluctuation in heat content, which would have to be taken into account in the design of any heat recovery installation.

As a comparison with the City of Edmonton data, some text book data is available. Table 3[4] shows the results of a study in New Jersey of an area with a population of 307,255 people. Although the components in the New Jersey study were categorized differently, the composition was generally similar. However, the New Jersey heat content was significantly lower.

TABLE 2

ANALYSIS OF TRANSFER STATION GRINDINGS 1976 (IN PERCENT)

EDMONTON

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	AVERAGE
PAPER	54.2	63.3	67.8	26.4	23.7	32.0	44.5
WOOD	1.3	1.8	1.6	3.3	5.0	2.6	2.6
CARDBOARD	12.3	11.5	9.4	8.1	6.3	11.4	9.8
GRASS	5.1	2.4	.1	34.0	36.8	24.3	17.1
PLASTIC	7.5	6.6	5.1	4.6	3.0	9.0	5.9
CLOTH	3.2	1.4	4.6	1.0	1.5	3.5	2.5
METAL	9.8	5.6	3.5	3.0	4.0	7.9	5.6
FOOD STUFF	NO ANALYSIS	2.8	1.4	.8	1.2	.8	1.4
MISC.	8.6	4.6	6.5	19.8	18.5	8.3	11.0
MOISTURE % WT.	38.0	35.5	39.2	34.4	36.1	37.9	36.8
CALORIFIC VALUE (BTU/lb)							
MOIST	4401	4935	4534	3738	3497	4223	4221
AIR DRY	7143	7562	7565	5717	5496	6815	6716

NOTE: MISC. = Inert portion composed of rock, glass and soil particles, etc.

SOURCE: E.W. & S., Unpublished Data

TABLE 3

"QUAD-CITIES" NEW JERSEY SOLID WASTES PROJECT

COMPOSITION OF SOLID WASTES

WASTE COMPOSITION	PERCENT	WASTE COMPOSITION	PERCENT
Municipal Wastes (2.74/lbs/cap/ day)		Industrial Wastes (3.31 lbs/cap/ day)	
Physical Composition		Physical Composition	
Paper	45.63	Paper	42.73
Wood	3.00	Wood	7.34
Plastics	2.52	Plastics	12.61
Glass	6.22	Glass	3.03
Sand, stone	7.65	Sand, stone	5.09
Organics	22.62	Organic chemical	3.32
Rags	4.45	Textiles, rags	3.28
Chemical Characteristics		Ceramics	1.57
as received		Inorganic chemical	0.19
Moisture	30.1	Petro-chemical	0.23
Volatiles	34.7	Rubber	2.45
Ash	35.2	Mixed commercial	4.15
B.T.U. value/lb.	3,364	Miscellaneous	4.43
Carbon/Nitrogen		Food	5.00
value on day basis - 31			

SOURCE: A.P.W.A., Municipal Refuse Disposal, 1970

FOOTNOTES

CHAPTER II - SOLID WASTES GENERAL INFORMATION

[1]Edmonton Water and Sanitation, Sanitation Annual Report - 1975(April 27, 1976), p.5

[2]Edmonton Water and Sanitation, Solid Waste Report (January, 1974), p.46

[3]Edmonton Water and Sanitation, Unpublished data re analysis of solid waste, 1975-76.

[4]American Public Works Association, Municipal Refuse Disposal, (1970), p.44

CHAPTER III

REVIEW OF ALTERNATIVE RECOVERY SYSTEMS

GENERAL BACKGROUND

The number of resource recovery systems in operation is large, and expanding very rapidly.

Since local conditions and size of operation significantly affect the cost of any given disposal alternative, it is impossible to predict the exact cost of any system at a specific location. The economics and feasibility of various disposal options are as shown in Figure 4[1]. This figure illustrates that sanitary landfill can be the lease expensive method of disposal. The potential advantages and disadvantages of the various systems are shown in Figure 5[2]. Each of the systems has advantages and disadvantages which help to suit that system for a given situation.

Typical examples of the various systems are discussed in this chapter. The coverage is not intended to be exhaustive, but it gives a reasonable representation of the various types of systems in operation, primarily in North America.

In many cases, the projects discussed are funded by Federal Government grants. In these cases, the projects do not necessarily have to meet all the conditions which favour that alternative. However, the projects are generally implemented in cases where conditions do not favour an economic sanitary landfill system for all refuse. In almost all cases, the need still exists for a landfill to accommodate

COMPARATIVE ECONOMICS AND FEASIBILITY OF
MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS

ALTERNATIVE	FEASIBILITY	NET OPERATING COST PER TON*
Sanitary landfill	Institutional - there may be active citizen opposition to potential locations. Technical - depends on geological characteristics of the land. Economic - decided savings in cost per ton if facility handles over 100 tons per day.	\$1.50-\$8
Conventional incineration	Technical - feasible. Economic - cannot economically meet new air pollution standards.	\$8-\$15
Small incinerator	Technical - feasible. Economic - varies with particular case.	\$8-\$15
Steam generation from waterwall incinerators.	Technical - several incinerators are in operation, only 2 are marketing the steam produced. Economic - markets for steam are limited.	\$4-\$10
Solid waste as fuel in utility or industrial boiler	Institutional - owner/operator must contract with utility for sale of electricity. Technical - combustion in utility boiler as supplement to coal has been demonstrated in St. Louis. Economic - practical feasibility depends on cooperation of local utility or user industry.	\$6-\$10

FIGURE 4 (Continued next page)

FIGURE 4
COMPARATIVE ECONOMICS AND FEASIBILITY OF
MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS (continued)

ALTERNATIVE	FEASIBILITY	NET OPERATING COST PER TON*
Pyrolysis: Solid waste converted into combustible gas and oil	Technical - has been demonstrated at 200 ton per day pilot plant. Economic - transportability and quality of the fuel produced are primary factors. Ability to store and transport fuel offers broad market application.	$4-$12
Heat recovery to generate steam	Technical - 1,000 ton per day plant is in shakedown operation in Baltimore. Air pollution problems have been encountered. Economic - markets for steam are limited.	$4-$8
Materials recovery: Newsprint, corrugated, and mixed office papers.	Technical - separate collection, possibly with baling, is required. Economic - markets are variable; when paper prices are high, recovery can be profitable.	
Mixed paper fibers	Technical - technology has been demonstrated at 150 ton per day plant in Franklin, Ohio. Economic - fiber quality from Franklin plant is low, suitable only for construction uses. Quality can be upgraded by further processing.	$7-$13
Glass and Aluminum	Technical - technology being developed. Economic - market potential is adequate but system economics uncertain as yet.	

FIGURE 4

SOURCE: U.S.E.P.A., DECISION MAKERS GUIDE

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS AND THE CONDITIONS THAT FAVOR EACH

ALTERNATIVE	POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES	CONDITIONS WHICH FAVOR ALTERNATIVE
Sanitary landfilling	Simple, easy to manage Initial investment and operating costs are low Can be put into operation in short period of time May be used to reclaim land Can receive most types of solid waste, eliminating the necessity for separation of wastes	Proper sanitary landfill standards must be observed or the operation may degenerate into an open dump. Difficult to locate new sites because of citizen opposition Leachate may create water pollution Production of methane gas can constitute a fire or explosion hazard Obtaining adequate cover material may be difficult	All solid waste systems must have a landfill for unprocessed waste or for the residues resulting from processing facilities.
Sanitary landfilling of baled solid waste	Extends life of landfill (double that of a fill for unprocessed wastes) Lowers operating costs at the disposal site Reduces hauling costs where distant sites are used	Resource recovery is precluded once bale is formed Leachate may create water pollution	Long hauls needed to reach landfill sites Shortage of landfill sites requires maximum utilization of available land

FIGURE 5 (continued on next page)

FIGURE 5
POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS AND THE CONDITIONS THAT FAVOR EACH (continued)

ALTERNATIVE	POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES	CONDITIONS WHICH FAVOR ALTERNATIVE
Sanitary landfilling of shredded solid waste	Extends life of landfill Does not require daily cover under some conditions Waste is more easily compacted and placed Vehicles do not become mired in waste in inclement weather Reduces problems with vectors Does not support combustion or lead to blowing litter Shredding at transfer station or at landfills may be first step in implementing a resource recovery system	Jamming and bridging of the feeding equipment can reduce through-put of the mill High level of component wear especially of hammers Danger to employees from flying objects, explosions, fires within the mills, and noise Leachate may create water pollution Maintenance and repair costs are high	Cover material is difficult to obtain Shortage of land-fill sites requires maximum utilization of available land
Incineration	Extends life of landfill May be more economical than hauling unprocessed waste to distant landfill	Large capital investment High operating cost Large expend-itures may be required for air pollution control equipment Conventional incinerators generate large quantities of wastewater which must be treated and disposed of	Land available for sanitary landfilling is at a premium Few if any conditions favor convention-al incineration

FIGURE 5 (continued on next page)

FIGURE 5
POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS AND THE CONDITIONS THAT FAVOR EACH (continued)

ALTERNATIVE	POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES	CONDITIONS WHICH FAVOR ALTERNATIVE
Materials recovery systems	Less land required for solid waste disposal High public acceptance Lower disposal costs may result through sale of recovered materials and reduced land-filling requirements	Technology for many operations still new, not fully proven Requires markets for recovered materials High initial investment required for some techniques Materials must meet specifications of purchaser	Markets for sufficient quantities of the reclaimed materials are located nearby Land available for sanitary landfilling is at a premium Heavily populated area to ensure a large steady volume of solid waste to achieve economies of scale
Energy recovery systems	Landfill requirements can be reduced Finding a site for an energy recovery plant may be easier than finding a site for a land-fill or conventional incinerator Total pollution is reduced when compared to a system that includes incineration for solid waste disposal and burning fossil fuels for energy	Requires markets for energy produced Most systems will not accept all types of wastes Specific needs of the energy market may dictate parameters of the system design Complex process requiring sophisticated management Needs relatively long period for planning and construction between approval of funding and full capacity operation	Heavily populated area to ensure a large steady volume of solid waste to take advantage of economy of scale Availability of a steady customer for generated energy to provide revenue Desire or need for additional low-sulfur fuel source Land available for sanitary landfilling is at a premium

FIGURE 5 (continued on next page)

FIGURE 5
POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS AND THE CONDITIONS THAT FAVOR EACH (continued)

ALTERNATIVE	POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES	CONDITIONS WHICH FAVOR ALTERNATIVE
	May be more economical than enironmentally sound conventional incineration or remote sanitary landfilling	Technology for many operations still new, not fully proven	
	High public acceptance		
	As cost of fossil fuel rises, economics become more favorable		

FIGURE 5

SOURCE: U.S.E.P.A., DECISION MAKERS GUIDE

some residue. However, each of the resource recovery systems removes some portion of the solid wastes from the amount which finally goes to landfill.

In some cases, where a particular need has been demonstrated state or province wide systems are being implemented to develop resource recovery alternatives to sanitary landfilling. Two examples of this are in the State of New York and the Province of Ontario.

In November 1972, the voters in New York State approved an Act that provides $175 million in funds for construction of solid wastes recovery and management projects[3]. The Act provides for State funding of up to 25% of the total eligible cost of waste disposal projects, and up to 50% of the cost of resource recovery projects. Of the $175 million, $171.5 million has been committed for resource recovery projects.

As of December 1975, 21 applications for funding of resource recovery systems had been received under the Act (See Figure 6). The list illustrates the diversity of projects throughout the State, dependent on local conditions. Figure 7 illustrates the degree of assistance under the Act for various types of projects. Naturally, the different degrees of assistance would tend to encourage the construction of projects eligible for the higher grants. To encourage the practice of resource recovery in rural communities, transfer stations are eligible for grants under the Act. This assists the rural communities to minimize the cost of transportation of refuse to regional resource recovery facilities.

STATUS OF RESOURCE RECOVERY FACILITIES IN NEW YORK STATE - DECEMBER 1975

MUNICIPALITY	DESIGN CAPACITY (TONS/DAY)	TYPE OF RESOURCE RECOVERY SYSTEM	PROTO TYPE SYSTEM	AREA SERVED	STATUS OF PROJECTS
New York City	1,500	Ferrous metals and supplemental fuel (RDF) recovery	PEPCO, Washington D.C.	Part of N.Y.C. represents one of eleven proposed resource recovery projects	Preliminary engineering underway
Hempstead	2,000	Material recovery and fuel for energy conversion	Franklin, Ohio	Part of Township of 900,000 population	Awaiting financing of project
North Hempstead	1,000	Shredding and ferrous metals recovery & baling	San Diego, CA	Town	In bidding phase
Smithtown	1,000	Ferrous metals recovery and manual separation of materials	St. Paul, MN	Town	Under construction
Chemung County	300	Ferrous metals and supplemental fuel (RDF) recovery	Madison, WI	County	Phase I (shredders) completed Testing Americology's air and glass recovery systems

FIGURE 6 (continued next page)

FIGURE 6 (continued)

STATUS OF RESOURCE RECOVERY FACILITIES IN NEW YORK STATE-DECEMBER 1975

MUNICIPALITY	DESIGN CAPACITY (TONS/DAY)	TYPE OF RESOURCE RECOVERY SYSTEM	PROTO TYPE SYSTEM	AREA SERVED	STATUS OF PROJECTS
Monroe County	2,000	Materials and supplemental fuel (RDF) recovery	St. Louis, MO	County	In final engineering design stage
Onondaga County	1,200	Ferrous metals and energy recovery	Nashville, TN	County	Phase I (shredders) completed Energy conversion system in design stage
Westchester County	3,000	Ferrous metals recovery, fuel gas and energy recovery	Charleston, WV Hamilton, Ontario	County	Engineering firm retained to design and manage project
Albany City	630	Ferrous metals and energy recovery	Hamilton, Ontario	City and portions of adjacent towns	Preliminary engineering underway
Oyster Bay	100	Composting of leaves and grass clippings	Shredding and windrow composting	Town	Under design
Suffolk County - Multi-town	3,000	Ferrous metals and energy recovery	Quebec, Canada	Three towns	Contracts for management, design and construction being executed

FIGURE 6 (continued next page

FIGURE 6 (continued)

STATUS OF RESOURCE RECOVERY FACILITIES IN NEW YORK STATE-DECEMBER 1975

MUNICIPALITY	DESIGN CAPACITY (TONS/DAY)	TYPE OF RESOURCE RECOVERY SYSTEM	PROTO TYPE SYSTEM	AREA SERVED	STATUS OF PROJECTS
Chautauqua County	600	Supplemental fuel (RDF) recovery	St. Louis, MO	County	Feasibility resource recovery study in progress
Dutchess County	700	Ferrous metals and fuel gas recovery	Charleston, WV	County	Preliminary engineering underway
Capital District	2,000	Ferrous metals and supplemental fuel (RDF) recovery	St. Louis, MO	Four Counties	Updating cost and market data
Niagara County	760	Ferrous metals and paper extractions, fuel gas recovery	Orchard Park, NY	County	Alternate proposals under review
Erie County	2,000	Ferrous metals and supplemental fuel (RDF) recovery	St. Louis, MO	County	Alternate proposals under review
Hempstead (Sanitary District #1)	500	Ferrous metals and fuel gas recovery	Charleston, WV	Five incorporated areas of Town	Engineering selection underway

FIGURE 6 (continued next page)

FIGURE 6 (continued)

STATUS OF RESOURCE RECOVERY FACILITIES IN NEW YORK STATE-DECEMBER 1975

MUNICIPALITY	DESIGN CAPACITY (TONS/DAY)	TYPE OF RESOURCE RECOVERY SYSTEM	PROTO TYPE SYSTEM	AREA SERVED	STATUS OF PROJECTS
Mt. Vernon (City)	200	Fuel gas recovery	Charleston, WV	Part of Westchester County	Developing management alternatives
Columbia County	150	Separation of materials	Hudson, NY	County	Phase I, landfill under design; separation concept under evaluation
Auburn City	200	Shredding and ferrous metals recovery	Madison, WI	City	Resource recovery study underway; multi-county program under review
Cortland County	140	Shredding and ferrous metals recovery	Madison, WI	County	Resource recovery study underway; multi-county program under review

ENERGY RECOVERY - Processed solid waste fuel fired 100% to produce steam
SUPPLEMENTAL FUEL- Refuse - derived fuel fired with coal or oil for power generation
FUEL GAS - High temperature pyrolytic conversion of the organic fraction of solid waste to a burnable fuel gas and inert slag.

FIGURE 6

SOURCE: WASTE AGE, MARCH, 1976

DEGREE OF ASSISTANCE

BASED ON THE EXTENT OF RECOVERY

	RESOURCE RECOVERY PROGRAM	N.Y. STATE ASSISTANCE PERCENT OF ELIGIBLE COST
1.	No recovery - Environmentally Sound Solid Waste Disposal System	25%
2.	Ferrous Metals Recovery	30%
3.	Ferrous and Non-Ferrous Metal Recovery	31%
4.	Metals and Glass Recovery	36%
5.	Paper Products, Metals and Glass Recovery	41%
6.	Solid, Liquid or Gaseous Fuel Recovery (e.g. RDF, Pyrolysis)	50%

FIGURE 7

SOURCE: WASTE AGE, MARCH, 1976

In the Province of Ontario the Environment Ministry has been engaged since 1971 in improving the method of handling of solid wastes[4]. Action has followed several basic approaches, including:

(a) Reducing the quantity of waste produced and applying restrictions on materials which eventually become waste.

(b) Projects to develop information on the feasibility of home separation of waste, and separate collection.

(c) Investigation of waste incineration as a source of steam for district or process heating or cooling.

(d) Investigation of the use of pulverized waste as a fuel in cement kilns.

(e) Investigation of burning of pulverized waste for power generation, combined with recovery of some of the materials.

As a first stage in implementing a resource recovery plan, the Province has offered to build immediately six processing plants for the municipalities involved. Figure 8 illustrates the process to be used. At these plants, the readily separable and marketable material such as corrugated paper, bundled newsprint, and ferrous metals will be removed for sale, and the remainder shredded. The plants will range in capacity from 200 to 1000 tons/day, and will serve the urban areas of the Province. The total cost of this first stage will be $17 million.

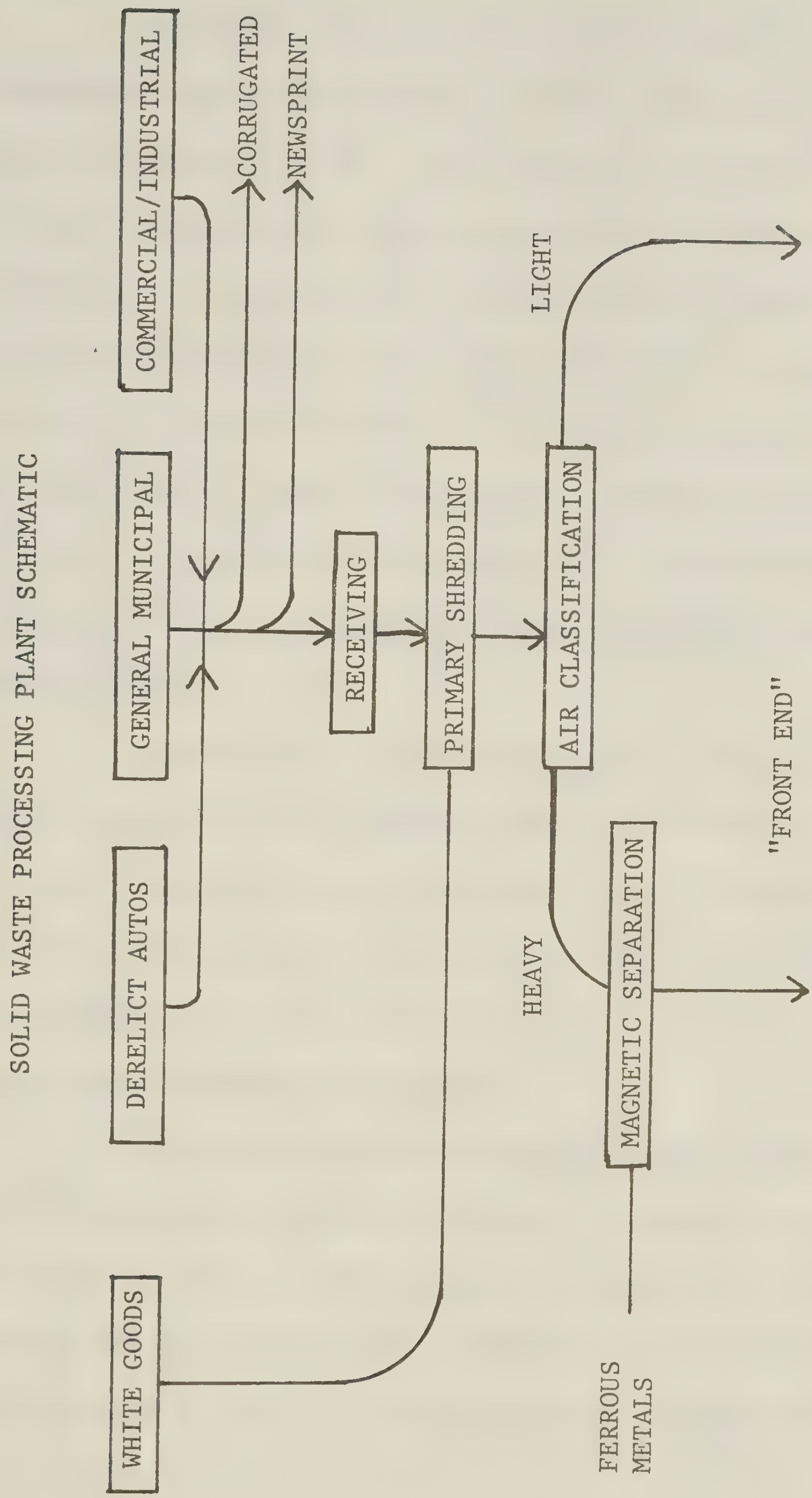


FIGURE 8

SOURCE: ENGINEERING JOURNAL, MARCH , 1975

ENERGY RECOVERY

The rising cost and decreased availability of energy from conventional sources are tending to make solid waste an increasingly attractive energy source. Until recently, steam recovery[5] coupled with waste incineration was the only energy recovery technology available. In recent years, there have been a number of new developments in energy recovery processes in electrical generation and chilling for air conditioning. The projects covered in this section are those that are almost exclusively oriented to energy recovery. The section on Mixed Systems deals with a number of projects which recover not only the energy, but also some of the original materials from the refuse.

The recovery of energy from solid wastes can result in mutual benefits for the community and the purchasers of the energy product. The community achieves lower waste disposal costs, less air pollution, and extended landfill life. The energy user receives reduced fuel costs, and a source of low-sulphur fuel.

Quebec Urban Community Incinerator

A steam generating incinerator[6] with a nominal capacity of 1000 tons per day commenced operation in Metropolitan Quebec City in 1974 (See Figure 9). That capacity is expected to meet the growing needs of the area up to 1981. Stringent[7] air pollution requirements are to be met by the use of efficient electrostatic precipitators.

FLOW DIAGRAM - QUEBEC INCINERATOR PLANT

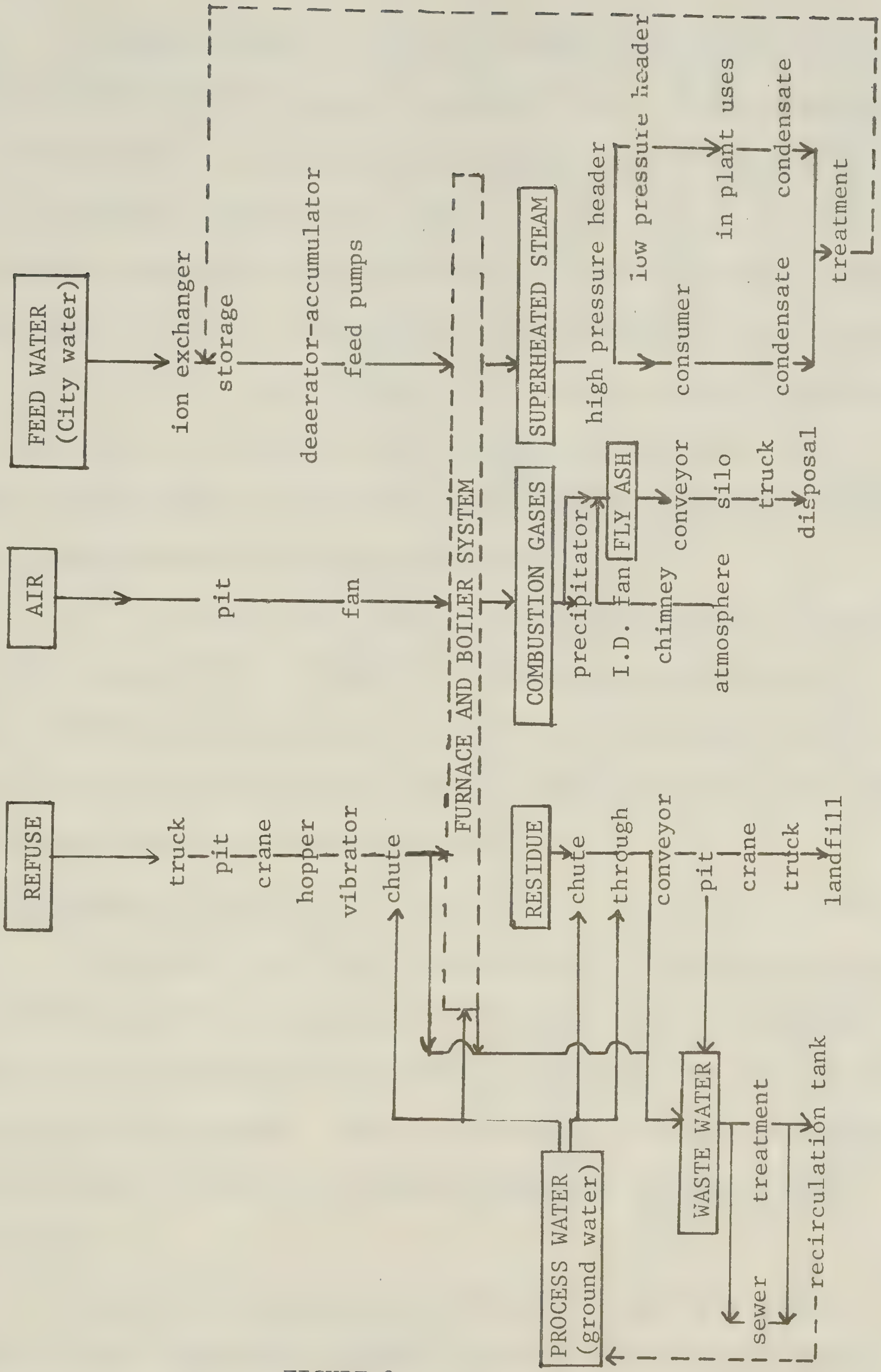


FIGURE 9
SOURCE: PROCEEDINGS OF NATIONAL INCINERATOR CONFERENCE

The incinerator is a Von Roll moving grate design, built by Dominion Bridge[8] with refractory clad water walls. At full combustion rate 324,000/lbs/hr. of steam will be produced at 680 psig and 315°C. All the available steam will be sold to a nearby pulp and paper plant, by long term agreement which calls for the steam flow rate to remain within limits of plus or minus 7% of the daily average flow. A unique heat accumulator has been built into the system to provide regulation to compensate for variations in heat content of the refuse. Oil burners are included in the furnace to provide for the supply of steam during interruptions in the supply of refuse.

As of October, 1975, the throughput for the year to date had been 383 tons per day. At this rate, operating costs (excluding capital amortization) amounted to $10 per ton. The dumping fee is set at $5.42 per ton, and it is expected that by 1976 this fee will defray the combined capital and operating costs.

City of Montreal Incinerator No. 3

Incinerator No. 3 (See Figure 10) was inaugurated in Montreal[8] on September 15, 1970. The plant was designed to produce 400,000[9] lbs/hr. of steam at 225 psig and 260°C., consuming 1200 tons per day of garbage in the process. The four furnaces are of Von Roll design, built by Dominion Bridge, with moving grates and refractory clad water walls.

The unit has been plagued since start up by the lack of steam sales and inadequate condenser capacity. The original design provided high pressure condenser capacity for only 147,600 lbs/hr. of

SECTION DIAGRAM MONTREAL MUNICIPAL INCINERATION

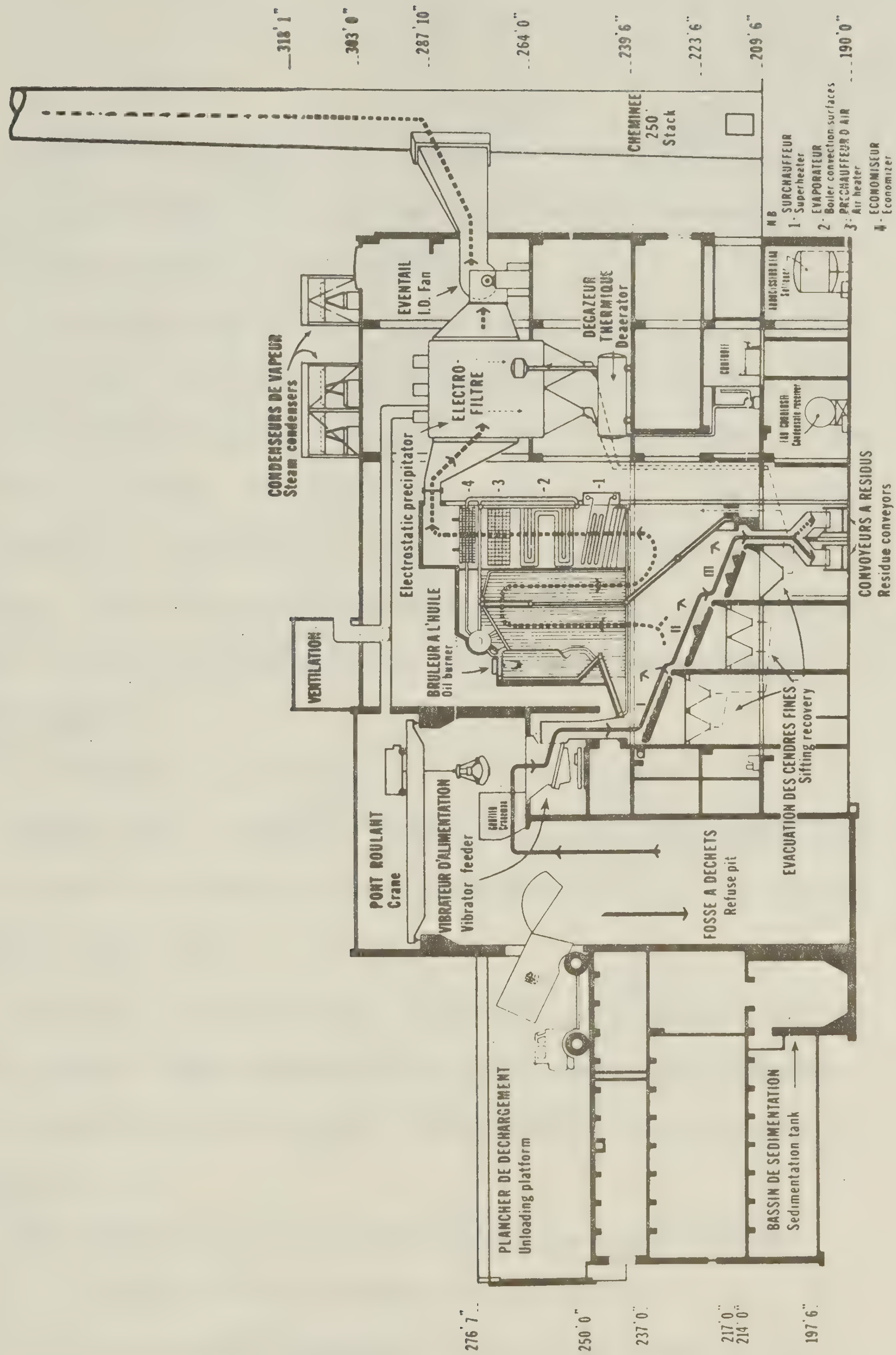


FIGURE 10

SOURCE: TECHNICAL DATA

steam.

Since the incinerator was started up without firm markets for the steam generated, the plant was restricted by condenser capacity to approximately 35% of capacity.

As of September 1975, the plant capacity was up to 440,000 lbs/hr.[10] of steam, with condensing capacity increased to 50% of full load. Building and feedwater heating plus limited steam sales provide condensation for another 16% of full load capacity. The plant should therefore be able to operate year round at 66% of capacity, or 800 tons per day. When in operation, snow-melting will use 100,000 lbs/hr., but that is sufficiently seasonal that it would not significantly increase throughput.

Information on operating cost is not available. However, at 66% of capacity with no significant steam sales, the amortization alone on the original $13.2 million capital investment would exceed $5/ton.

Ottawa Master Plan Study

By using a "total systems " approach[11], the National Capital Commission and the Federal Department of Public Works have completed a complex economic analysis to rate thirty-four different projects (See Figure 11) for:

(a) Generating steam for heating and cooling of federal buildings in the downtown core of Ottawa.

(b) Economically disposing of solid wastes generated in Ottawa, in view of a desire to curtail the continued use

DESCRIPTION OF THE PROPOSALS STUDIED

OTTAWA MASTER PLAN STUDY

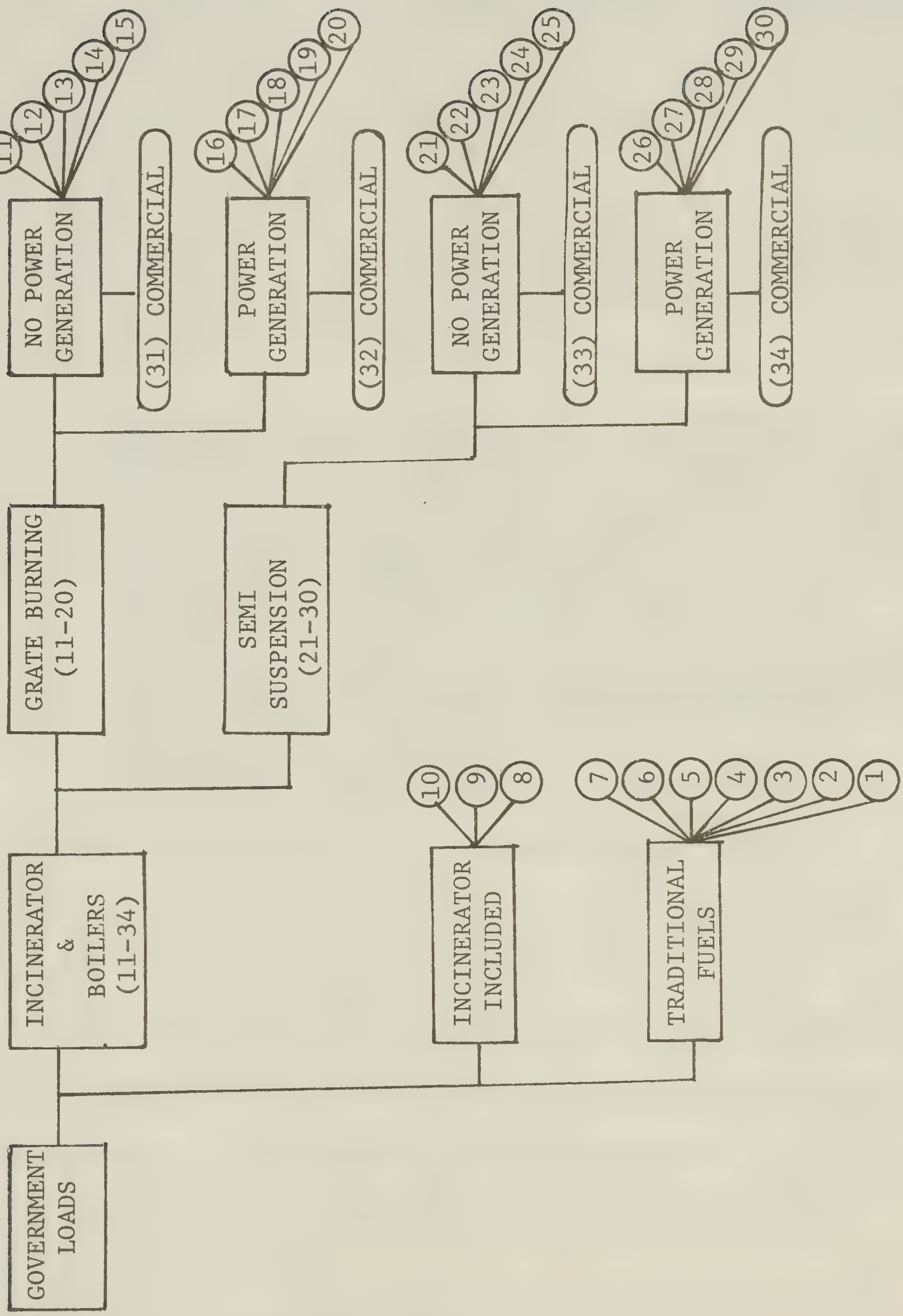


FIGURE 11

SOURCE: OTTAWA - MASTER PLAN STUDY

of Federally owned landfill sites for municipal solid waste disposal.

(c) Possibly generating power from the steam before charging it to the system.

(d) Possibly selling steam for heating and cooling use to privately owned buildings in the downtown core.

In the "Summary of Results" the report states:

> " In the absence of waste management considerations the Department of Public Works would select a conventional fuel system as the most economical system to provide its clients with heating and cooling services. An analysis of the cost differential indicates, however, that a support charge of from $4 to $7 per ton of garbage would compensate for the additional costs associated with the incinerator system. As this charge compares favourably with the costs which municipalities are currently paying for trucking and dumping waste in landfill sites a broader perspective would dictate the selection of a network which includes a waste incineration plant as one of the energy sources."

The study concludes that a combined waste/conventional fuel fired steam plant should be built, to begin steam production in 1978. The cost of the semi-suspension burning installation will be between $21 - $50 million[12]. The initial materials reclamation will be for ferrous metals, aluminum and zinc, with expansion later to other materials. The system will generate steam for heating and cooling of private as well as public buildings, plus generate electric power in the plant.

Nashville Thermal Transfer Corporation

The City of Nashville, Tennessee is the location of an

innovative project to use the heat generated[13] from the combustion of solid wastes for heating and cooling of downtown office buildings. Thermal is providing heat and/or cooling to twenty-eight buildings through an underground piping system which was installed during an urban renewal program. The Plant is designed to burn 100,000-120,000 tons of garbage per year and the system cost was originally $16.5 million.

There are two boilers (See Figure 12) designed for grate burning of unprocessed refuse, and a standby fossil-fueled boiler for maintaining system continuity. The volume reduction on the refuse burned is 95%, so that there is little refuse left from the plant for the landfill. Thermal burns 25% of the community refuse, so that the remaining 75% is still landfilled.

The most significant[14] problem which is still to be overcome is Thermal's inability to meet air quality requirements since going on stream in July, 1974. The best air quality attainable with the wet scrubbers is approximately 0.17 grains per standard cubic foot, compared to a regulatory requirement of 0.08. Thermal intends to install an electrostatic precipitator on one boiler, and evaluate a bag-house unit on the second. Depending on the evaluation, they will install either a precipitator or a bag-house on the second boiler. The air quality is to be improved by early 1977 to the regulatory requirement.

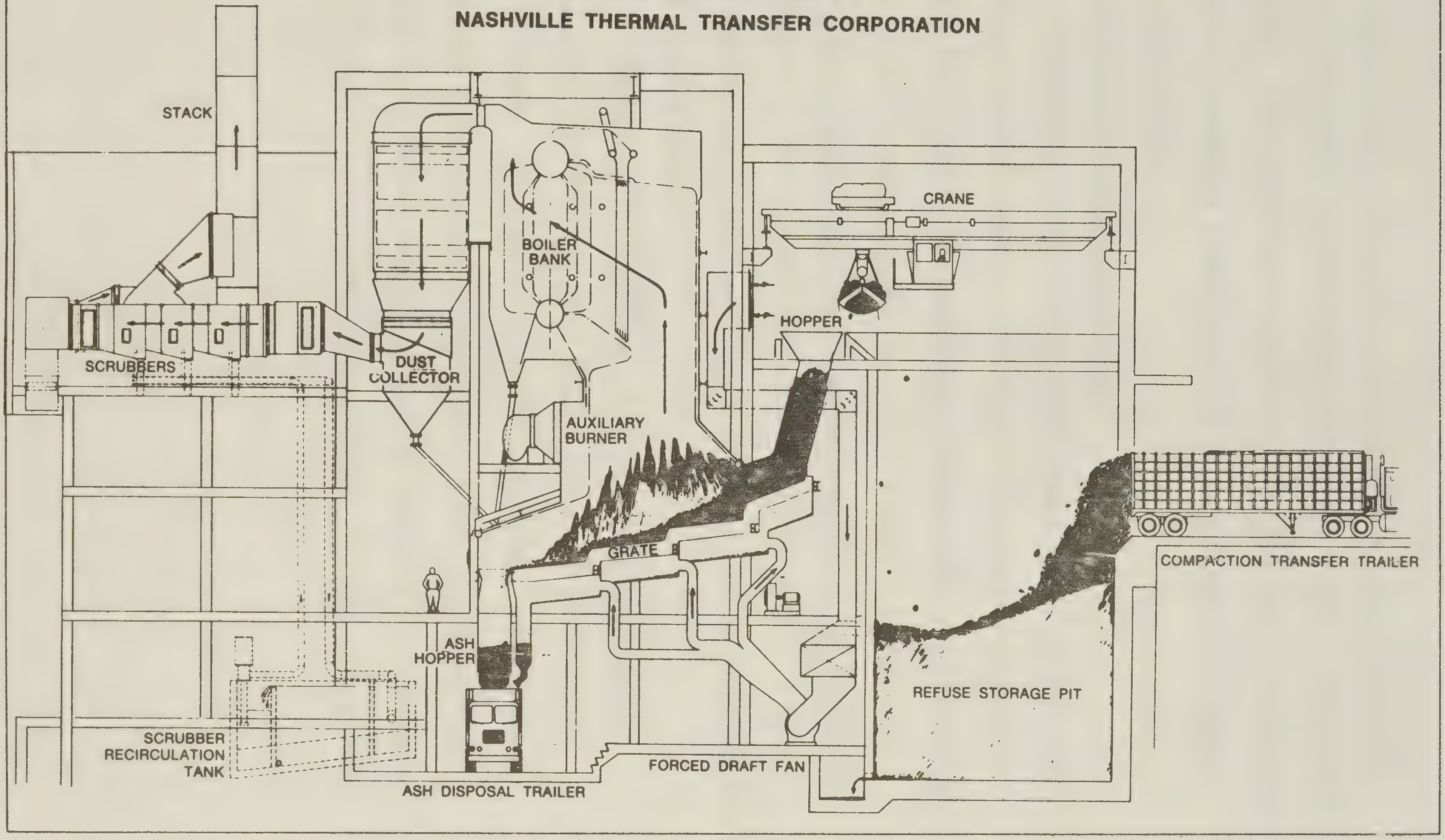
Thermal is a not-for-profit corporation supplying heating

FIGURE 12

SOURCE: A.P.W.A. REPORTER, DECEMBER 1975

HEATING PLANT

NASHVILLE THERMAL TRANSFER CORPORATION



and cooling at cost. The rates in September, 1975 were $6.88 per 1000 pounds of steam and $0.76 per ton hour for cooling. These rates are slightly less than fossil fuel heating in Nashville. Additional funding, and presumably higher rates, will be required for the air quality improvements.

Winnipeg Solid Waste Management Study

The City of Winnipeg appointed consultants[15] in late 1975 to perform a $150,000 study of solid waste management in the City. The report is to provide a comprehensive program for collection and disposal of solid wastes in the City. The study is to emphasize the economic feabilility and environmental merits of material and energy recovery. One of the likely uses to be studied[16] is as a fuel in the generation of steam and/or hot water for an existing central district heating system.

Manitoba Hydro presently operates a central district heating system providing steam to heat a number of buildings in central Winnipeg. The system presently burns coal, and the study will consider the economics of supplementing the coal with solid waste fuel. The report, which was jointly funded by the Province of Manitoba and the City of Winnipeg, has not yet been made public.

MATERIAL RECOVERY

Materials recovery[17] from solid wastes can take many forms, ranging from salvaging only one readily marketable product from the refuse (cream-skimming) to salvaging virtually every identifiable component. The system practiced in any given location will depend on the content of the refuse, and the markets in the area. The more common systems will be in the mid-range of the spectrum, salvaging two or three materials, such as ferrous metals, bundled paper, and possibly glass. The plants discussed are those which are generally not involved in energy recovery.

Experimental Plant for Resource Recovery - Ontario Ministry of the Environment

The Ontario Ministry of the Environment and Metro Toronto are cooperating[18] on a cost sharing arrangement in the construction of a resource recovery plant (See Figure 13)[19] to be one of the six under the Province's plan. Cost of the plant, located adjacent to the Dufferin Street Incinerator in North York, are being borne two-thirds by the Ministry and one-third by Metro. The plant will handle approximately 200[20] tons of refuse per day and arose out of a two-volume report prepared for the Ministry by Kilborn Engineering Ltd. Resource recovery is expected to begin in June, 1977.

The first stage in the operation consists of hand removing the marketable, clean corrugated cardboard, and visually inspecting the refuse stream for hazardous materials. The refuse stream is then shredded and air classified into a heavy fraction and a light

EXPERIMENTAL PLANT FOR RESOURCE RECOVERY

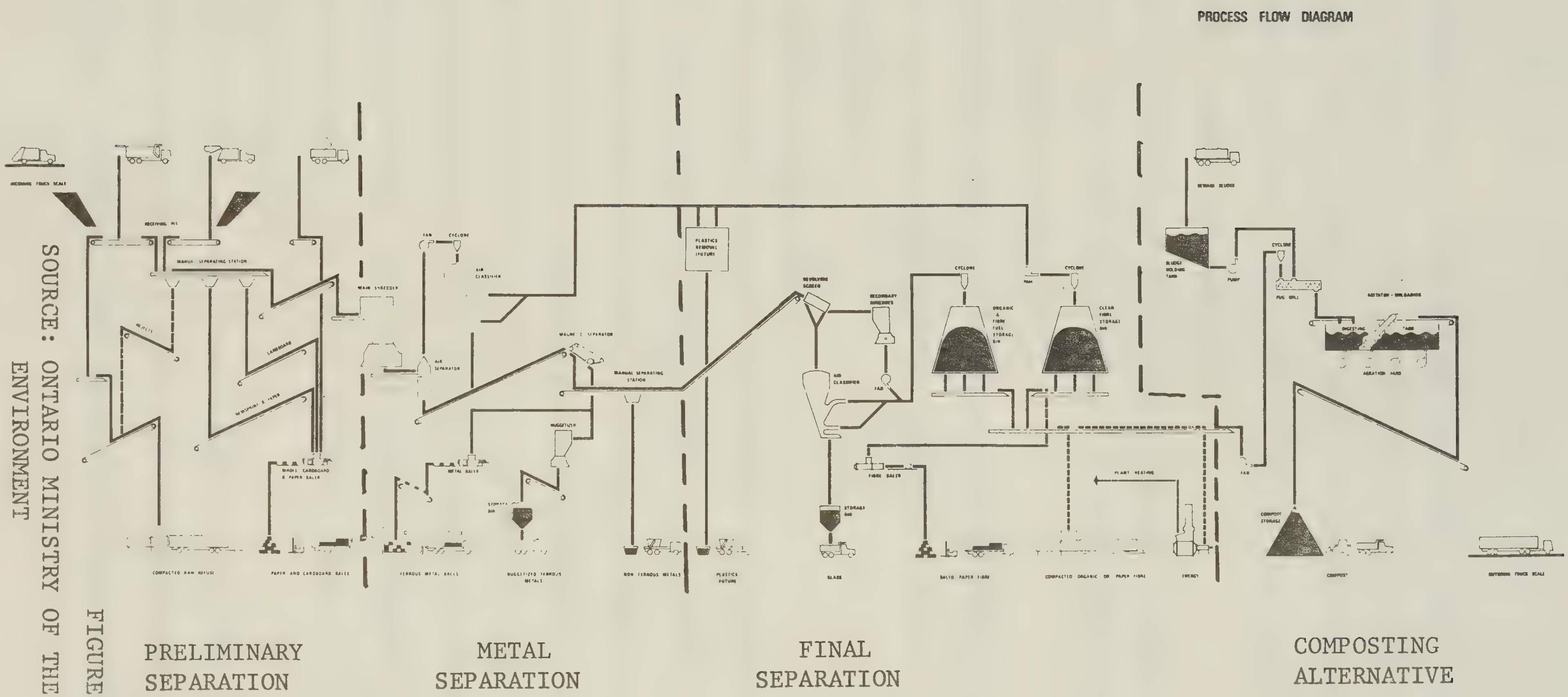


FIGURE 13

SOURCE: ONTARIO MINISTRY OF THE ENVIRONMENT

clean fibre fraction. It is expected that the clean fibre will be either used for cardboard or paper box manufacturing, or for fuel. The heavy fraction will be further processed to remove ferrous metals, non ferrous metals and glass. The residue will be mixed with water or sewage sludge, digested and composted.

The plant is intended to be a research and demonstration plant to determine the economics of various processes and to explore the markets for recovered materials.

Although the costs of operation are not yet known, they are predicted to be greater than sanitary landfill but less than conventional incineration.

Recovery I - New Orleans, Louisiana

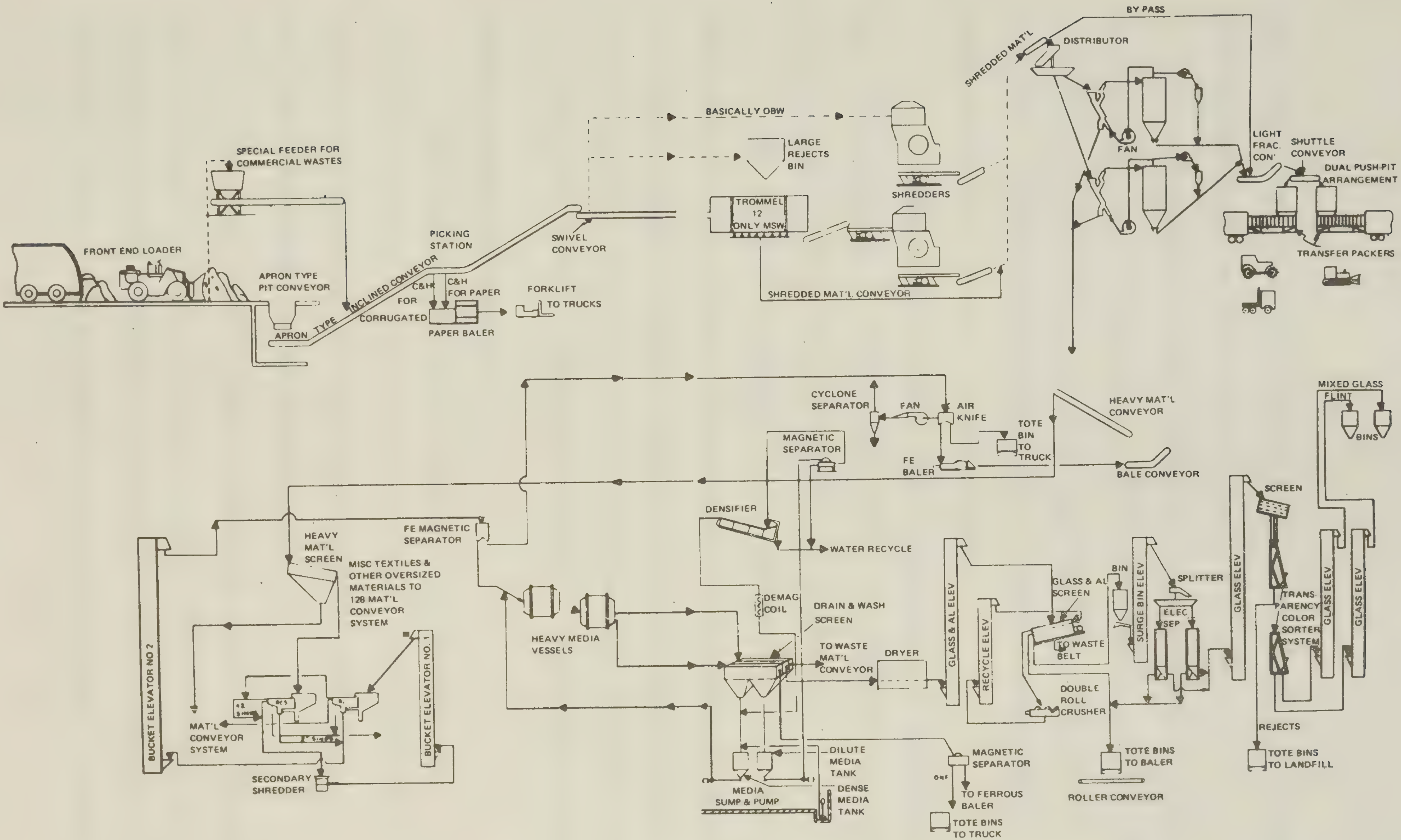
A $6.5 million[21] shredding and resource recovery facility (See Figure 14) began operation in New Orleans in July 1976, with shredding now in operation and resource recovery to begin in June, 1977[22]. The facility will be operated by Waste Management Inc., a private company in the field of solid waste management, under a three-way agreement with the City of New Orleans and the National Center for Resource Recovery, Inc. The plant will accept 650 tons per day[23], about one-half of the City's municipal waste, at a cost to the City of $10.95 per ton.

At the time that construction commenced, letters of intent[24] had been received from six private firms to purchase products of the facility as follows: aluminum, light ferrous (tin can) bundles,

FIGURE 14

RECOVERY I EQUIPMENT FLOWSHEET

SOURCE: CITY OF NEW ORLEANS


FRONT END LOADER
SPECIAL FEEDER FOR COMMERCIAL WASTES
APRON TYPE PIT CONVEYOR
APRON TYPE INCLINED CONVEYOR
PICKING STATION
C&H FOR CORRUGATED
C&H FOR PAPER
PAPER BALER
FORKLIFT
TO TRUCKS
SWIVEL CONVEYOR
BASICALLY OBW
LARGE REJECTS BIN
TROMMEL 12 ONLY MSW
SHREDDERS
SHREDDED MAT'L CONVEYOR
SHREDDED MAT'L
DISTRIBUTOR
BY PASS
FAN
LIGHT FRAC. CON'
SHUTTLE CONVEYOR
DUAL PUSH-PIT ARRANGEMENT
TRANSFER PACKERS
CYCLONE SEPARATOR
FAN
AIR KNIFE
TOTE BIN TO TRUCK
FE BALER
HEAVY MAT'L CONVEYOR
BALE CONVEYOR
MAGNETIC SEPARATOR
DENSIFIER
WATER RECYCLE
FE MAGNETIC SEPARATOR
HEAVY MAT'L SCREEN
MISC TEXTILES & OTHER OVERSIZED MATERIALS TO 128 MAT'L CONVEYOR SYSTEM
BUCKET ELEVATOR NO 2
BUCKET ELEVATOR NO. 1
MAT'L CONVEYOR SYSTEM
SECONDARY SHREDDER
HEAVY MEDIA VESSELS
DEMAG COIL
DRAIN & WASH SCREEN
TO WASTE MAT'L CONVEYOR
DRYER
DILUTE MEDIA TANK
DENSE MEDIA TANK
MEDIA SUMP & PUMP
GLASS & AL ELEV
RECYCLE ELEV
GLASS & AL SCREEN
TO WASTE BELT
BIN
SURGE BIN ELEV
SPLITTER
ELEC SEP
DOUBLE ROLL CRUSHER
TOTE BINS TO BALER
ROLLER CONVEYOR
MAGNETIC SEPARATOR
TO FERROUS BALER
TOTE BINS TO TRUCK
GLASS ELEV
SCREEN
TRANS PARENCY COLOR SORTER SYSTEM
GLASS ELEV
GLASS ELEV
REJECTS
TOTE BINS TO LANDFILL
MIXED GLASS
FLINT
BINS

heavy ferrous and other non-ferrous, flint (clear) glass, flint and colour-mixed glass, and paper (No. 1 news).

The process provides for hand removal of bundled newspaper and corrugated prior to shredding. The shredded refuse will be air classified and the light fraction will initially go directly to landfill[25]. In the future this material, largely combustibles, may be used by the City as a source of energy.

The heavy fraction will then be mechanically, optically, and electrostatically sorted into the other salvageable components, with the unusable heavy fraction also going to landfill.

The term of the contract is for twelve years, but the $10.95 per ton cost to the City is subject to adjustment to offset the effects of cost escalation. Under the terms of the agreement, N.C.R.R. and the City will share 15% of the proceeds from the sale of the recovered products, and Waste Management will keep the rest.

Resource Recovery In Houston

The Metropolitan Waste Conversion Corporation[26] is operating a resource recovery system in Houston. They feel that the most economical and environmentally acceptable approach to solid waste management is resource recovery.

They hand-sort to recover cardboard, newsprint, aluminum and other white and red metals (zinc, brass). Ferrous metals are magnetically removed from the heavy stream of an air classifier, and mixed - colour glass is separated by a gravity table. Approx-

imately 60% of the incoming waste is extracted as a low grade mixed paper which they call "Fibre-Fuel". A market had not yet been developed for the fuel in 1974.

In 1974, the City of Houston was paying Metropolitan a disposal cost of $6.08 per ton of refuse delivered.

MIXED SYSTEMS

The most common energy recovery systems also include some degree of materials recovery as well. This can not only improve the economics of the process from revenues derived from sale of salvaged materials, but also improve the handling qualities of the fuel. As an example, the removal of metal and glass can drastically reduce the wear rate on pneumatic pipeline systems and the slagging on furnace grates and tubes. Typical examples have been taken from a large number of operations for discussion in this section.

Watts From Waste

To explore one of the approaches being considered under the Ontario Resource Recovery System, a contract[27] has recently been let by Metro Toronto for design of a "Watts From Waste" system. (See Figure 15)[28]. The system provides for the processing of 225,000 metric tons per year of raw solid waste, to produce 180,000 metric tons of fuel. The fuel will be burned in Ontario Hydro's Lakeview generating station, to replace up to 15% of the coal normally fired.

It is expected that the processing plant will initially recover ferrous metals for sale, remove the remaining heavy materials for landfilling, and send the light materials to the Hydro plant. As economic conditions warrant, the heavy materials could be processed further to recover aluminum, copper and other non-ferrous metals, along with crushed glass.

BASIC PROCESS - WATTS FROM WASTE

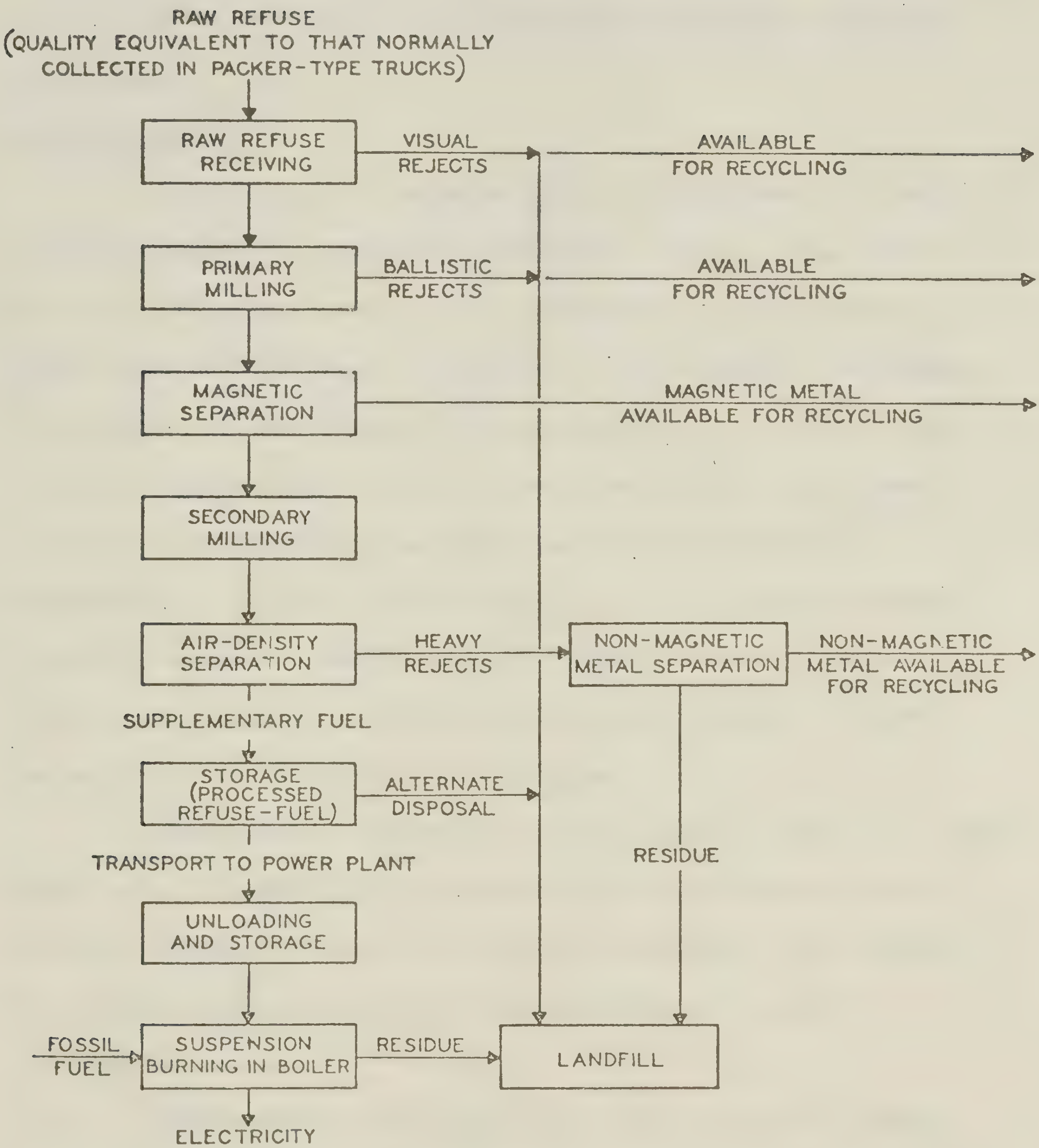


FIGURE 15

SOURCE: WATTS FROM WASTE STUDY

The 1973 economic analysis indicated that, after credit for fuel and ferrous metals, the net cost of disposal would be $8.83 per metric ton. That cost compared favourably with the alternate cost of $10.10 per metric ton for disposal in a steam generating incinerator.

Hamilton Swaru

In 1971 - 72 an advanced design of solid waste recovery unit (See Figure 16) was built in Hamilton, Ontario. The capacity was to be 600 tons per 24 hour day, producing 210,000 lbs/hr of steam based on 6000 BTU/lb. of refuse. After weighing, the refuse is shredded and transported by conveyor belt to two boilers. Most of the combustion takes place in suspension. Thus, grate temperatures are maintained low and glass and metals do not melt. Provisions are included for recovery of metal and glass, as market conditions warrant. Satisfactory air quality is met by use of electrostatic precipitators for cleaning stack gases. A volume reduction of 97% is achieved in the process.

The plant was designed to produce steam for sale, but the design also provided for 100% condensation of the steam through in-plant machinery drives and air-cooled condensers. This enabled the plant to operate as an incinerator whether steam sales materialized or not.

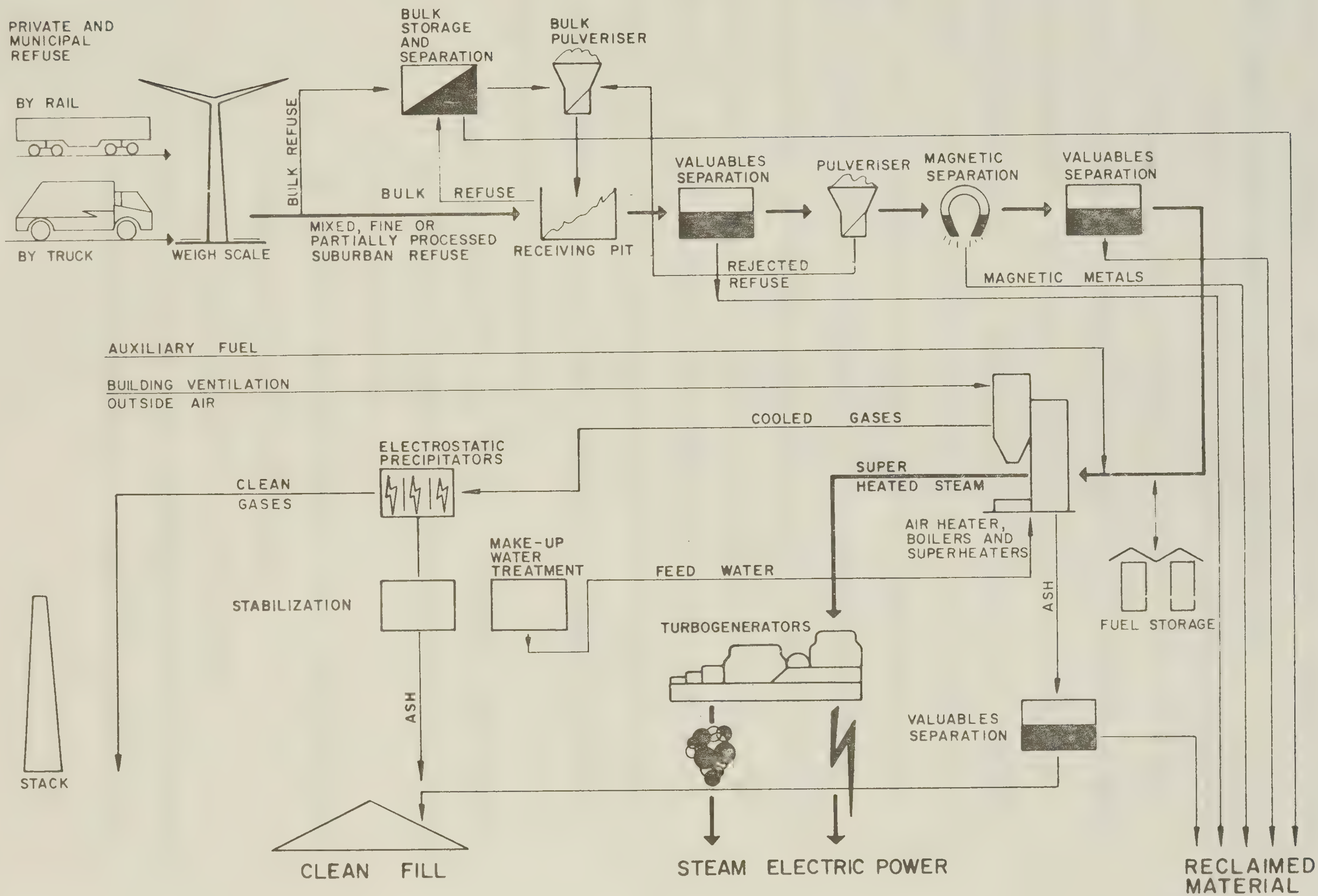
Unfortunately, the plant has not yet attained[30] design capacity. Modifications are underway to bring the plant up to

FIGURE 16

PROCESS FLOW CHART - SWARU

SOURCE: SOLID WASTE DISPOSAL RESOURCE RECOVERY SYSTEM

PROCESS FLOW CHART



capacity, and integrate it into the Ontario resource recovery scheme.

Waste Separation and Disposal System - Franklin, Ohio

Franklin's[31] solid waste processing facility, developed by the Black Clawson,Co., has a designed capacity of 150 tons per 24 hour day operation. The design (See Figure 17)[32] is based on paper-making technology. The process, called the Hydrasposal System, consists primarily of a wet pulper, a liquid cyclone and fluidized bed incinerator. All wastes delivered to the plant are fed to the pulper which is somewhat similar to a kitchen sink disposal unit. Water is mixed with the solid wastes in the pulper and soft and brittle materials are ground into a slurry. Non-pulpable materials such as metal and cans are thrown out the side of the pulper for recovery. The end products of the process are a wet paper pulp, ferrous metal, aluminum, and glass which has been sorted by color. The non-recoverable portion of the solid wastes stream is burned in the fluidized bed incinerator.

Operating since 1971, the Franklin plant has demonstrated:

(a) The volume of material going to the landfill has been reduced by over 95%.

(b) The plant has been so reliable that it has never been necessary to divert trucks away.

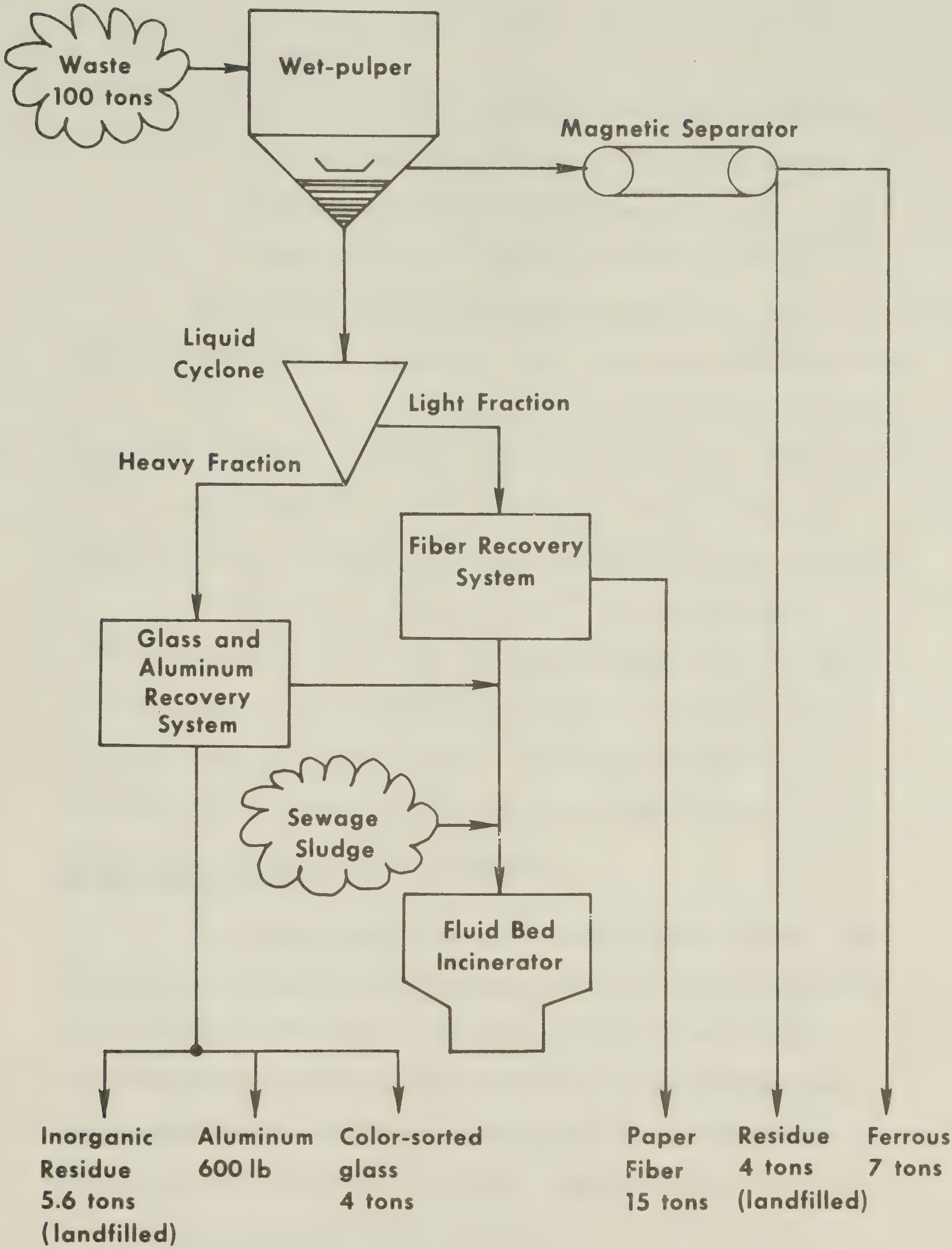
(c) Ferrous metals are being sold for re-use.

(d) Paper fibres are being recovered and sold to a nearby paper plant for making felt paper for asphalt roofing

FIGURE 17

A SIMPLIFIED FLOW CHART USING WET PROCESSING

SOURCE: U.S.E.P.A., RECOVERING RESOURCES FROM SOLID WASTE USING WET PROCESSING


Waste
100 tons
Wet-pulper
Magnetic Separator
Liquid
Cyclone
Light Fraction
Heavy Fraction
Fiber Recovery
System
Glass and
Aluminum
Recovery
System
Sewage
Sludge
Fluid Bed
Incinerator
Inorganic
Residue
5.6 tons
(landfilled)
Aluminum
600 lb
Color-sorted
glass
4 tons
Paper
Fiber
15 tons
Residue
4 tons
(landfilled)
Ferrous
7 tons

shingles.

(e) The non-recovered combustible material is combined with raw sewage sludge and the mixture burned in the fluid bed incinerator without auxiliary fuel. The exhaust gases meet Federal air emission standards.

As of March, 1974, costs were projected for a more economical 500 tons per day plant. The projections indicated a net cost of $4.20 to $11.40 per ton, depending on the markets and the prices for recovered materials. The energy conversion efficiency of the overall system is 52.6%. The fuel produced[33] offers an energy source with between 4,000 and 4,360 BTU/LB of heat content.

The same Black-Clawson process[34] will be used in an 11,000 ton per week plant to go on stream in Hempstead, New York in 1978. Both energy and materials recovery will be involved in the plant, now under construction. The refuse derived will be burned on site to produce 250 million kw of power annually.

Power Generating Solid Waste Incinerator At Edmonton, England

The Greater London Council[35] opened a plant in May, 1971 to generate electrical power from the combustion of more than 1000 tons per day of solid waste. The plant includes five boilers generating steam at 625 psig and 455^{o} C. The steam drives four 12.5 megawatt turbo-generators feeding power to the electrical utility and two 2.5 megawatt units for internal needs.

Refuse is delivered to the plant eight hours per day, five days per week. Refuse is stored in a deep bunker to provide for continuous operation of the power generators. The refuse is burned without processing on rotating grates. Flue gases are cleaned by electrostatic precipitators to meet existing air quality standards.

Ferrous metals are recovered from the ash by means of an overhead magnet, and are then sold. The ash also is sold. The plant experienced a number of start up difficulties and required considerable modifications to make it fully operational. It has been in full-scale operation since April, 1974. Since that time, 378,000 tons of refuse were incinerated in the first twelve months at a net cost, after credits, of $13.15 per ton. In view of the high cost of alternative methods of disposal, this is condidered to be an acceptable cost.

Ames, Iowa Resource Recovery System

The City of Ames, Iowa[36] opened a new 50 tons per hour resource recovery facility in September, 1975. The plant (See Figure 18) includes two stage shredding[37], magnetic separation for ferrous metal recovery, and air classification to separate out the light, combustible fraction. The fuel is pneumatically conveyed a distance of 800 feet for firing in a City owned power plant. The shredded solid wastes will replace about 12% of the coal normally burned at maximum load, saving[38] 22,000 tons per year of coal. The non-ferrous metal is separated from the heavy fraction out of the air classifier, for recovery and sale.

AMES IOWA

PROCESS FLOW DIAGRAM

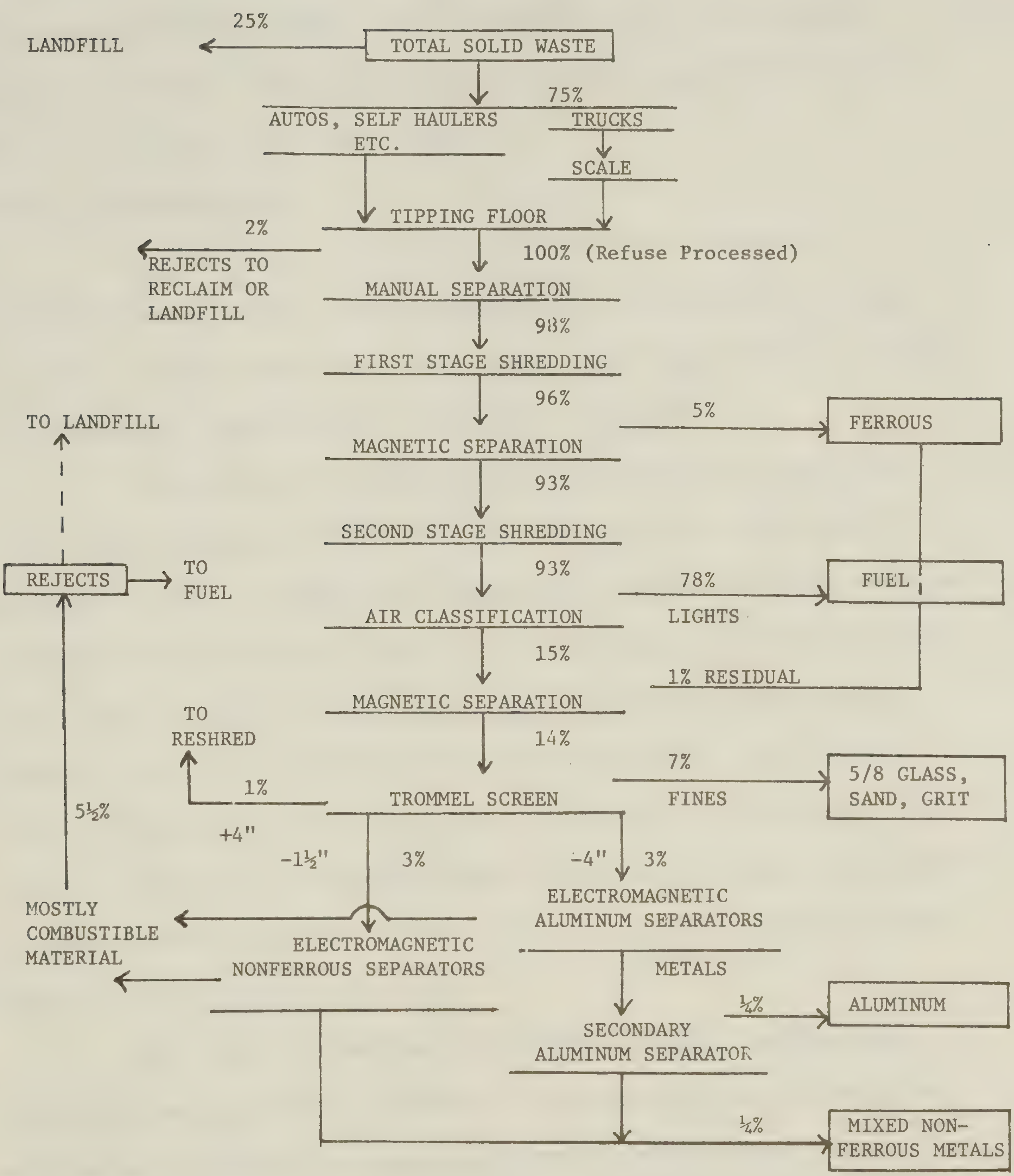


FIGURE 18

SOURCE: WASTE AGE, OCTOBER, 1975

Operating data is not yet available, but the City projects net cost for disposal of refuse of $1.20 per ton at 1975 costs. That compares with a recent cost of $2.50 per ton for sanitary landfill at Ames. These figures do not include amortization of the $5.56 million cost of the plant.

Saugus, Massachusetts

A consortium of private companies have combined in Massachusetts to build a steam generating[39] refuse disposal plant to serve sixteen communities. The plant (See Figure 19)[40] is similar to, but larger than the plant in Montreal, Quebec[41].

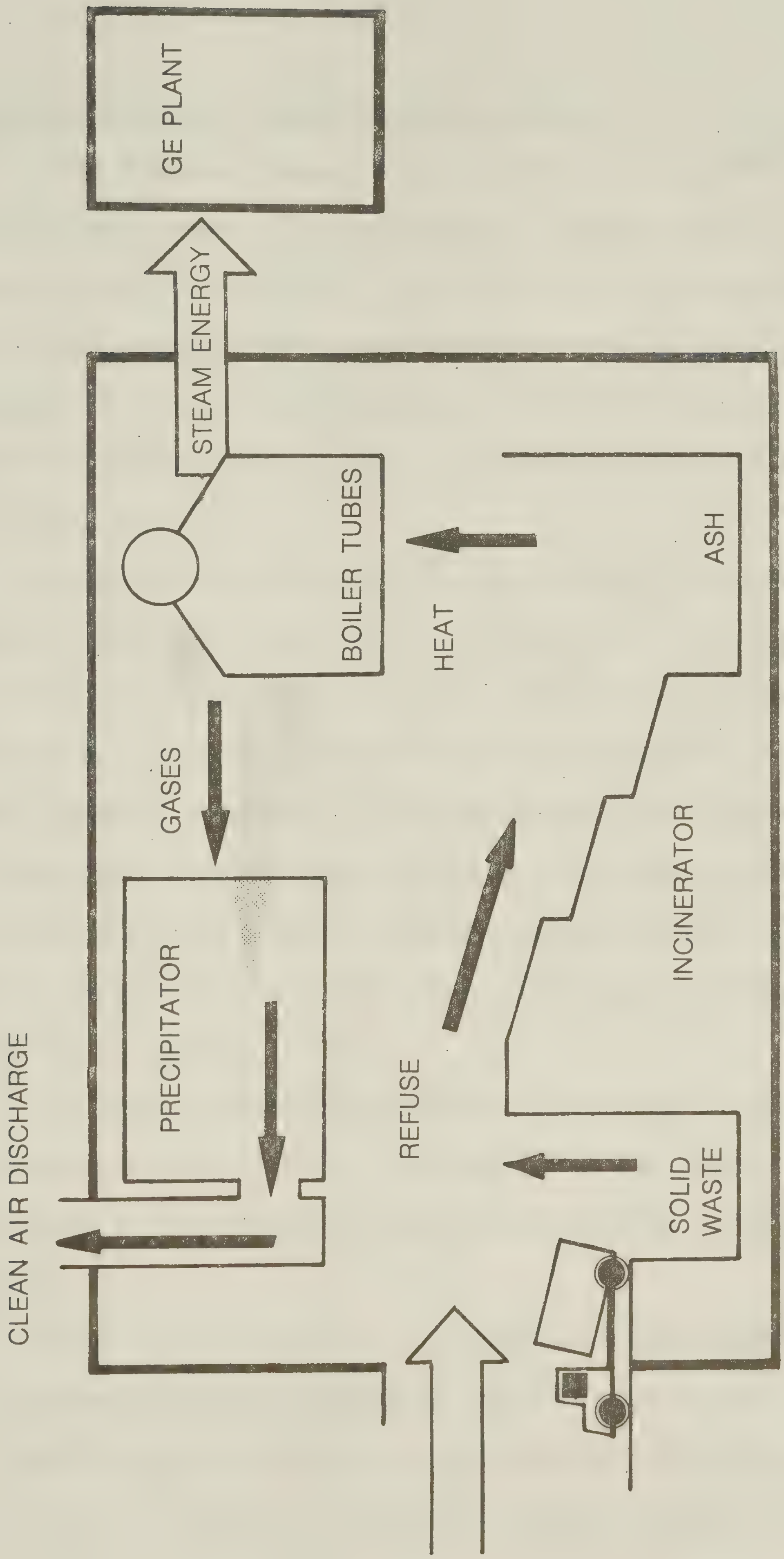
The privately financed plant, in operation for one year cost[42] approximately $43 million, and can dispose of 1200 tons of garbage per day. In addition to generating steam, the plant reclaims the metal from the solid wastes, at an estimated rate of 250 million steel cans per year. The two steam generators burn unprocessed refuse, producing 370,000 pounds per hour of steam. The steam is sold to a nearby manufacturing plant for use in their process. The volume of the refuse for landfilling is reduced to 10% of the original. Seventeen million gallons of fuel oil will be saved annually by the substitution of solid waste fuel.

The plant is designed to be non-polluting and meet all applicable environmental standards. The stack gases from the plant are cleaned to 99% purity by electrostatic precipitators.

FIGURE 19

SAUGUS ENERGY PLANT PROCESS

SOURCE: CLEAN ENERGY FROM REFUSE


GE PLANT
STEAM ENERGY
BOILER TUBES
HEAT
ASH
GASES
INCINERATOR
PRECIPITATOR
REFUSE
CLEAN AIR DISCHARGE
SOLID
WASTE

St. Louis Union Electric Energy Recovery Project

Union Electric Company plans, by 1977, to burn 8000 tons per day[43] of solid waste in conjunction with coal-burning for power generation. Union Colliery Co., a subsidiary of Union Electric, will build the system without government subsidy or cost to users of electricity. The capital and operating costs of the project will be financed from dumping fees, sale of recovered metals, and sale of fuel to the utility.

The system (See Figure 20)[44] will include five truck-to-rail transfer stations, accepting refuse from public and private trash haulers. The refuse will travel by rail[45] to one of the two power plants for processing. The process will include two stage shredding, magnetic separation of ferrous metals, glass removal, and air separation into a burnable fraction. The burnables will be blown into the power generation boilers, replacing up to 20% of the coal normally burned at full load. The energy[46] conversion efficiency of the process is 65%.

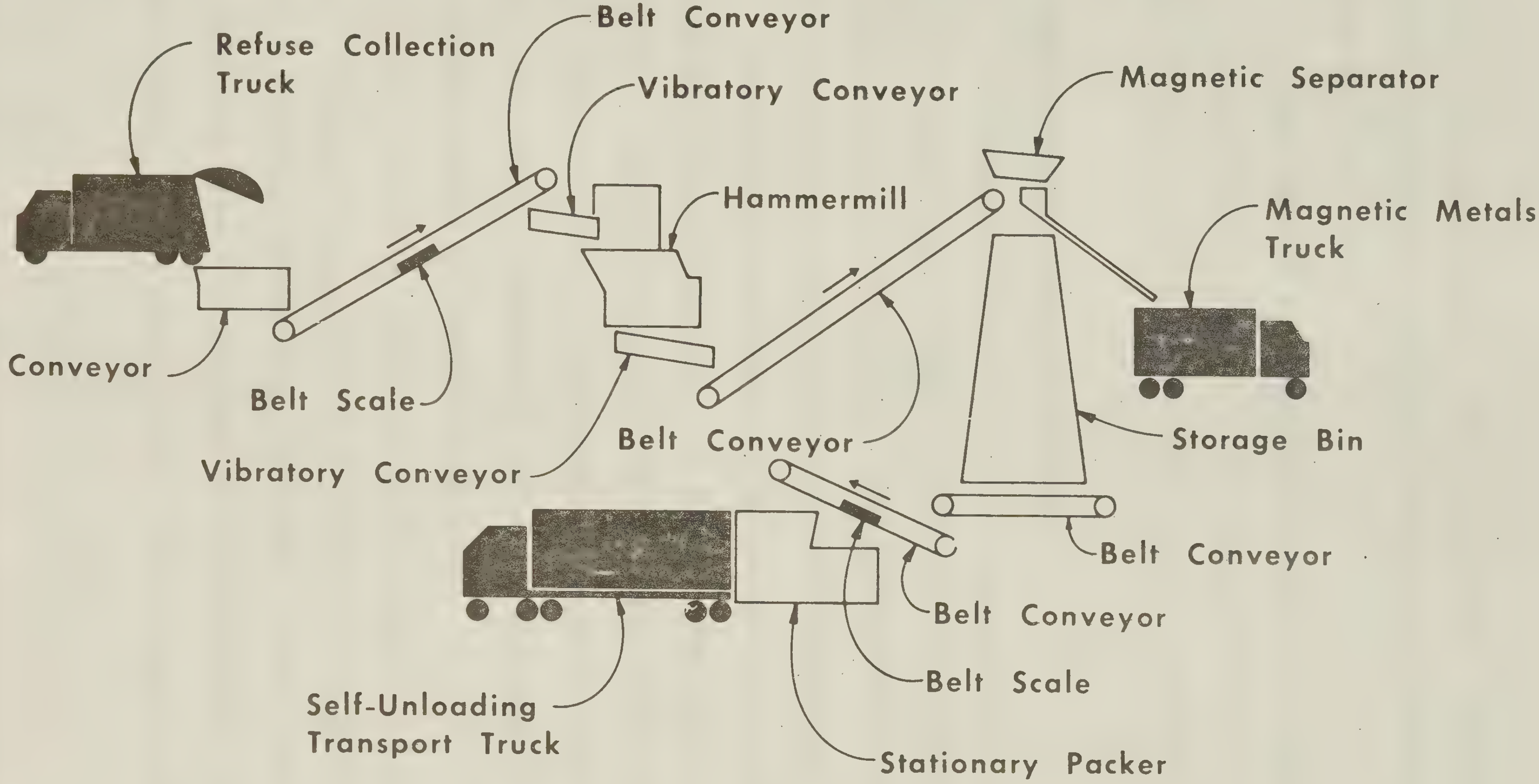
The system is based on experimental work with 50,000 tons of residential solid waste. This background has enabled Union Electric to resolve most of the process problems in the pilot plant stage.

Union Colliery expect a 15 - 16% return on investment from the systems based on a dumping fee of $6 per ton in 1978. Present landfill fees in the area are approximately $2 per ton. However, Union Colliery expects to attract adequate refuse to their

FIGURE 20

REFUSE PROCESSING FACILITIES

SOURCE: U.S.E.P.A., ENERGY RECOVERY FROM WASTE



REFUSE PROCESSING FACILITIES

transfer stations as a result of their convenience. The project is currently encountering considerable difficulty in obtaining the last transfer station site.

A comparison of the important properties of refuse versus coal is shown in Table 4. The calorific value of refuse is shown to be somewhat less than half that of coal, and the ash content about double.

Americology Process in Milwaukee, Wisconsin

In January, 1975, the City of Milwaukee signed a long-term contract[47] for solid waste recovery by American Can Company's Americology process (See Figure 21). The construction of the 1200 tons per day plant, presently in start-up, cost $18 million.

About 20% of the refuse will be reclaimed in the form of usable steel, tin, aluminum, paper and glass. About 60% will be supplied as a supplementary fuel to the Wisconsin Electric Power Company. The fuel will have the energy equivalent to 75,000 tons of coal. The refuse is shredded on arrival at the plant, followed by air classification and magnetic separation.

The 20% residue from the Milwaukee plant will be landfilled. The Americology process is designed for an alternative method of operation, incorporating pyrolysis. In that case, the 80% of the solid waste not reclaimed would be pyrolyzed. The products in that process would be low - BTU fuel gas, an oil and char.

TABLE 4

COMPOSITION OF RESIDENTIAL SOLID WASTE

AND COAL SAMPLES

(AS RECEIVED)

	REFUSE * (%)	COAL + (%)
Proximate Analysis		
Moisture	19.69 - 31.33	6.20 - 10.23
Ash	9.43 - 26.83	9.73 - 10.83
Volatile	36.76 - 56.24	34.03 - 40.03
Fixed Carbon	0.61 - 14.64	42.03 - 45.14
BTU per Pound	4,171 - 5,501	11,258 -11,931
Ultimate Analysis		
Moisture	19.69 - 31.33	6.20 - 10.23
Carbon	20.45 - 33.47	61.29 - 66.18
Hydrogen	3.38 - 4.72	4.49 - 5.58
Nitrogen	0.19 - 0.37	0.83 - 1.31
Chlorine	0.13 - 0.32	0.03 - 0.05
Sulfur	0.19 - 0.33	3.06 - 3.93
Ash	9.43 - 26.83	9.73 - 10.83
Oxygen	15.37 - 31.90	9.28 - 16.10

* From three samples of St. Louis residential solid waste, with magnetic metals removed.

+ From three samples of Union Electric Company coals.

SOURCE: U.S.E.P.A., ENERGY RECOVERY FROM WASTE

FIGURE 21

HOW AN AMERICOLOGY FACILITY WORKS

SOURCE: AMERICOLOGY RESOURCE RECOVERY FACILITY


Filtered air
Light paper/fiber fraction
Compacted for fuel, fiber recovery or other uses
Heavy refuse
Shredded residue for further processing such as pyrolysis, composting or landfill
Air classification
Magnetic separation
Shredding
Magnet
Magnet
Aluminum
Vibrating screen
Clean corrugated and newspapers
Aggregate
Raw refuse
Ferrous metals
Marketable materials out
Air classification
Compaction
Administration
Shredding
Corrugated and newspapers off
Control room
Raw refuse in

PYROLYSIS

Pyrolysis[48] is the thermal decomposition of materials in the absence or near-absence of oxygen. The high temperature and the starved air situation cause a breakdown of the materials[49] into three parts:

(a) a gas consisting primarily of hydrogen, methane, and carbon monoxide.

(b) a liquid fuel that includes organic chemicals such as acetic acid, acetone and methanol.

(c) a char consisting of almost pure carbon, plus any glass, metal, or rock that may have been processed.

The design of the individual system determines which of these outputs will be the predominant product. High temperatures favour gas formation, while lower temperatures favour the formation of liquids.

Pyrolysis processes are under development by a number of private and public organizations, in an attempt to develop a system that can convert solid waste into a storable, transportable fuel.

In a true pyrolysis operation involving no oxygen, the gas should have a heating value as high as 500 BTU per standard cubic foot. Partial oxidation processes will yield a gas with a heating content in the range of 300 - 400 BTU per standard cubic foot. If air is used as the source of oxygen for the reaction, the heating value will be cut approximately by one-half, due to the presence of nitrogen.

The oil produced has a heating value approximately one-half that of residual oil, with a low sulphur content. Problems could result from the significant ash content in the pyrolysis oil.

The char produced can be used as a fuel and also possibly as an adsorption agent. However, these uses are limited due to low volatility and inconsistency in composition.

Baltimore Pyrolysis Facility

Near the centre[50] of urban Baltimore, with excellent highway access, is the site for a pyrolysis unit opened in 1975. The plant is a 1000 tons per day version of the Landgard process developed by Monsanto, and originally cost approximately $20 million (See Figure 22)[51].

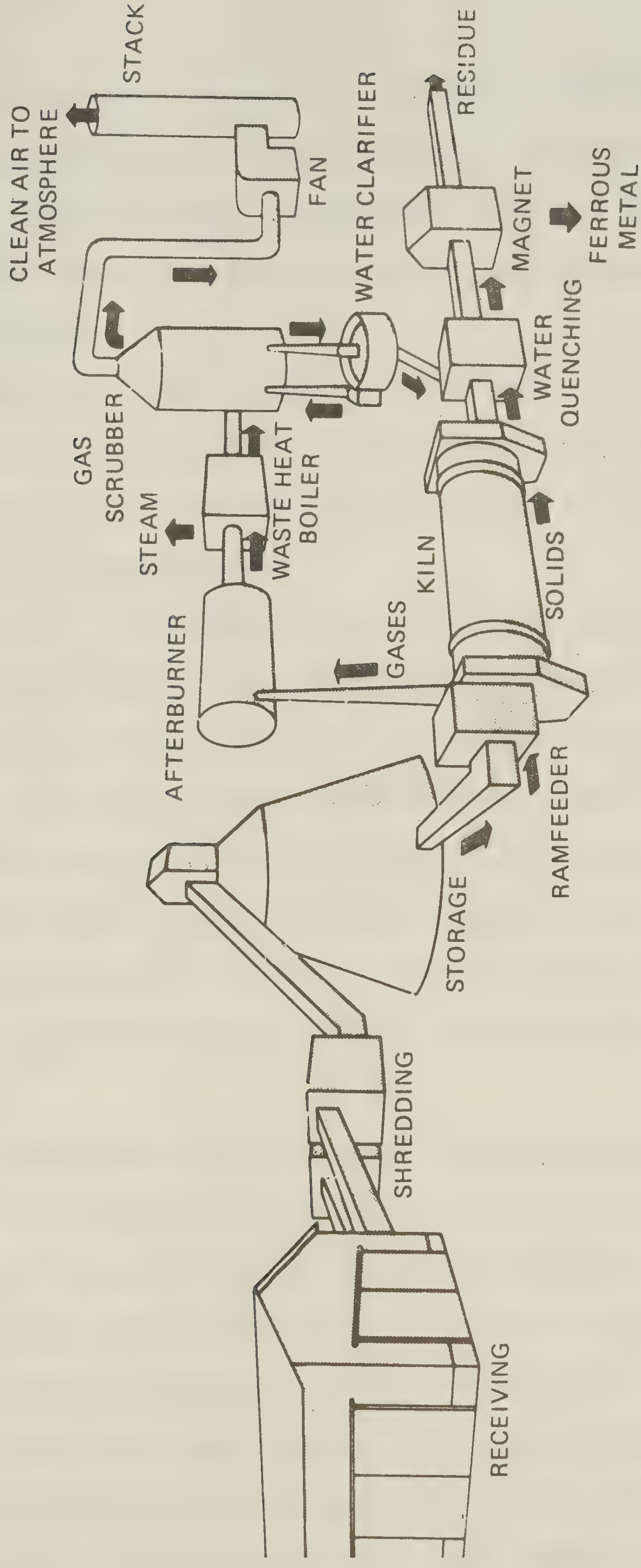
The incoming waste is weighed, shredded and conveyed to a transfer tower. From there, it goes either to storage or to a rotary kiln. After a residence time of twenty minutes in the kiln, the products are hot gases at 760^{o} C., char, and the inert inorganic materials which have passed through the reactor. The gases are combusted and the heat is used to generate 200,000 lbs/hr. of steam. The steam goes to a central steam distribution system, where it is used to heat downtown buildings. The ferrous metals are salvaged and a glassy aggregate remains for landfilling if no beneficial use can be found.

The primary problems encountered have been mechanical failure, and inability to meet air quality standards. The initial

FIGURE 22

BALTIMORE PLANT FLOW DIAGRAM

SOURCE: U.S.E.P.A., BALTIMORE DEMONSTRATES GAS PYROLYSIS


RECEIVING
SHREDDING
STORAGE
RAMFEEDER
AFTERBURNER
GASES
KILN
SOLIDS
STEAM
WASTE HEAT BOILER
GAS SCRUBBER
WATER QUENCHING
WATER CLARIFIER
MAGNET
FERROUS METAL
RESIDUE
FAN
CLEAN AIR TO ATMOSPHERE
STACK

construction included wet scrubbers for air quality control, but these have not met prevailing effluent standards. Tests have indicated that a wet electrostatic precipitator will meet air quality standards, and an additional $3 million will be spent to install this equipment.

It now appears that the cost of refuse disposal in this plant will be approximately equal to those of a water wall incinerator once the problems have been overcome, in the vicinity of $5 per ton.

San Diego County Pyrolysis Facility

The County of San Diego is planning[52] for start up of a 200 tons per day pyrolysis facility in El Cajon in May, 1977. The turn key plant is being constructed by Occidental Research Corporation Ltd. The Plant is expected to achieve a volume[53] reduction of 79% to significantly extend the life of the few remaining landfill sites[54] within economical distance of the County's population centres. The total capital investment is expected to be approximately $14 million, including the first year of operation.

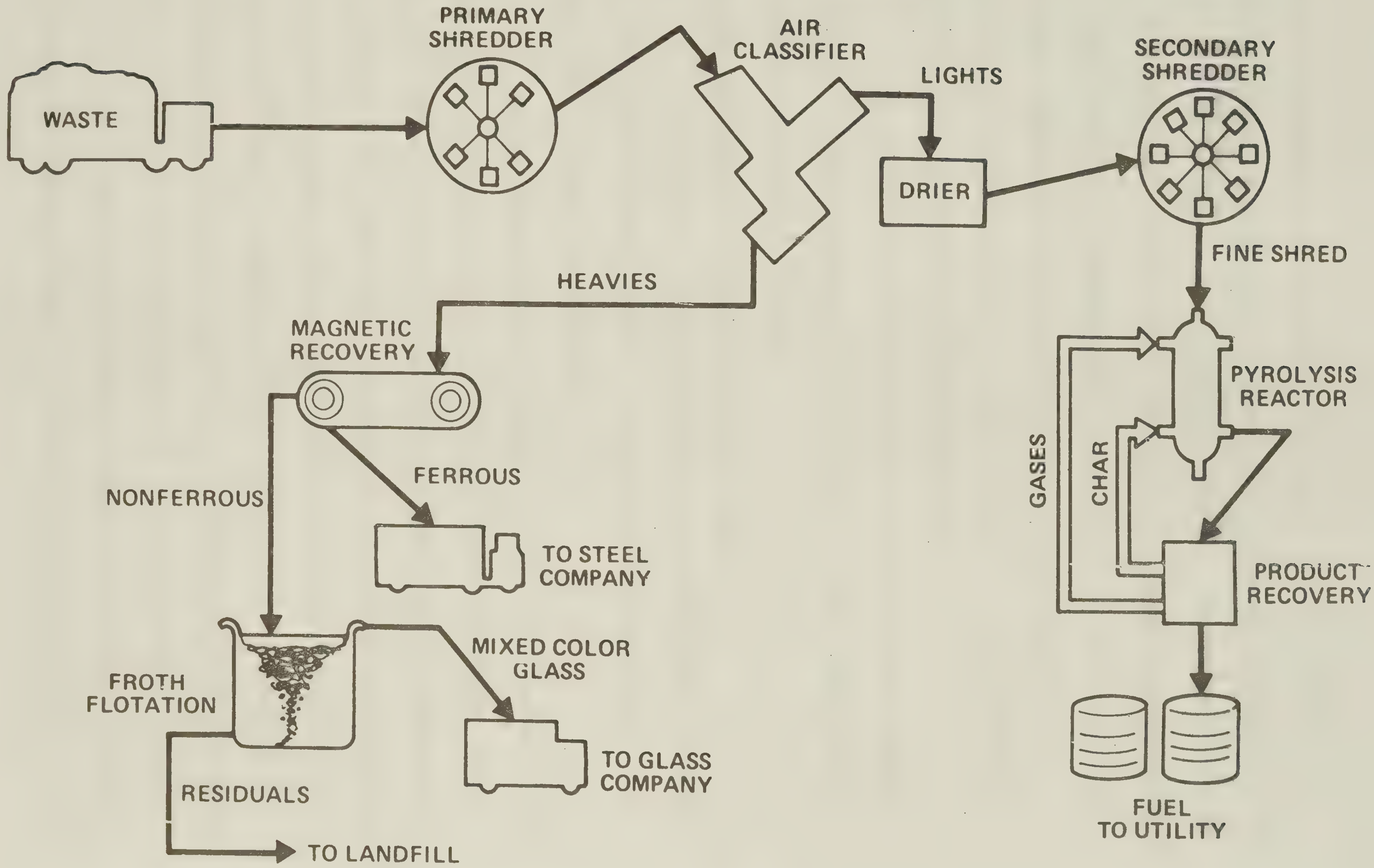
The process (See Figure 23) was developed by Occidental as an extension of research on liquification of coal, and then proven on a four tons per day pilot unit in Vancouver, Washington.

The refuse will be delivered to the plant by collection vehicles, and weighed on arrival. A 1000 hp shredder will reduce the refuse to a three inch size, followed by air classification. The "heavies" will be separated into ferrous metal and glass, for sale, and residuals, for landfill disposal. The "lights" will be

FIGURE 23

SOURCE: U.S.E.P.A., SAN DIEGO COUNTY DEMONSTRATES PYROLYSIS OF SOLID WASTE

BASIC STEPS OF THE PROCESS



dried and shredded to a nominal size of minus 14 mesh (80% of the particles could pass through a screen having fourteen openings to the inch), before feeding to the pyrolysis reactor. The products of the pyrolytic reaction will be char, which will be landfilled, and fuel oil. The fuel[55] oil, approximately thirty six U.S. gallons per ton of refuse processed, will be used by San Diego Gas and Electric Company for power generation. The process air will be cleaned in bag filters, to minimize air quality problems.

The total system operating cost, including amortization, is expected to be approximately \$20 per ton. Larger units would probably be more cost-effective.

Purox Process in South Charleston, West Virginia

A gaseous fuel[56] is produced by the Union Carbine "Purox" pyrolysis process being tested in the 200 tons per day plant (See Figure 24)[57] at South Charleston.

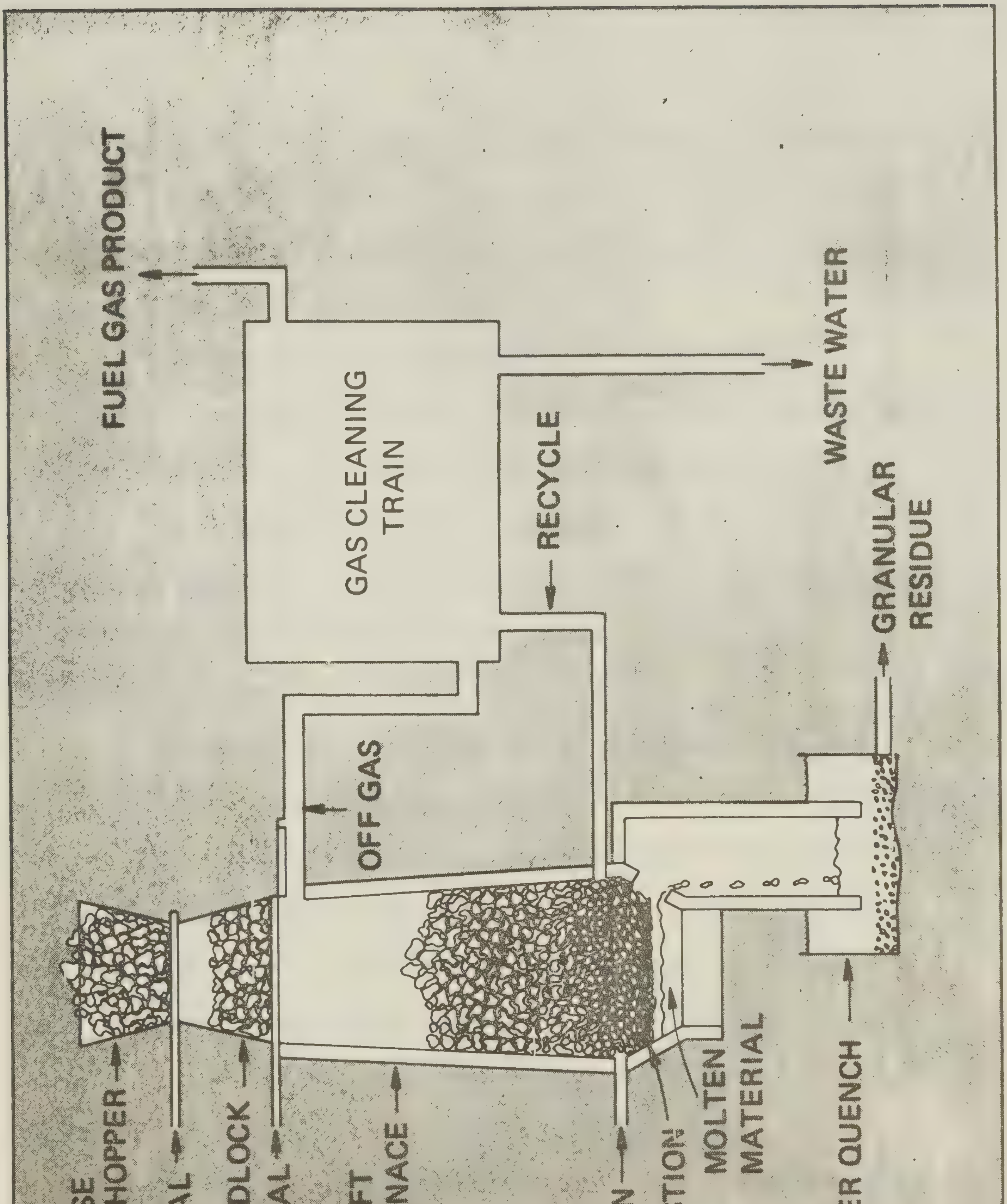
The incoming refuse is shredded to minux six inches, then passed below a magnetic separator to remove ferrous metals. The shredded refuse is then injected into the oxygen refuse converter. The converter is a vertical shaft furnace, with oxygen supplied from an on-site cryogenic air separation unit. The temperature in the forty foot[58] high furnace is 1600 to 1700^{o} C. The temperature fuses all non-combustible materials to a molten slag which is drawn off at the bottom and water-quenched to a sterile granular frit.

The clean-burning gaseous product of the plant is similar in combustion characteristics to natural gas, with a heating value[59]

FIGURE 24

OXYGEN REFUSE CONVERTER

SOURCE: UNION CARBIDE, SOLID WASTE DISPOSAL RESOURCE RECOVERY


FUEL GAS PRODUCT
GAS CLEANING
TRAIN
RECYCLE
WASTE WATER
OFF GAS
REFUSE
FEED HOPPER
SEAL
FEEDLOCK
SEAL
SHAFT
FURNACE
OXYGEN
COMBUSTION
ZONE
MOLTEN
MATERIAL
WATER QUENCH
GRANULAR
RESIDUE

of 350 to 370 BTU per standard cubic foot. The gas is essentially free of sulphur compounds or nitrogen oxides. It can be substituted for natural gas in an existing boiler by enlarging the burner nozzle to increase the flow rate.

The "Purox" plant incorporates an electrostatic precipitator so that it produces no stack emissions. The energy conversion efficienty of the plant is approximately 65%.

Experimental operation of the South Charleston plant is continuing, with tests beginning in April, 1977, of burning of sewage sludge combined with shredded refuse.

Andco Torrax System

A 200 tons per day Andco Torrax (See Figure 25)[60] solid waste conversion unit is being purchased[61] by the City of Frankfurt, Germany. The unit will be used to supplement existing conventional incinerators presently in use in Frankfurt. It will be designed for household waste, to which will be added tires and the fly ash from the electrostatic precipitators of the conventional incinerators. There are presently two other Andco-Torrax units under construction[62] in Europe, in Luxemburg and in Southern France.

The Andco-Torrax System, referred to as a slagging pyrolysis process, is designed to convert mixed municipal refuse into usable heat energy by completely oxidizing all combustible materials, and by melting non-combustible materials at temperatures up to 1650° C. Refuse is processed without sorting or pre-treatment. The system is reported to operate without secondary pollution to land, air or water.

ANDCO TORRAX SYSTEM

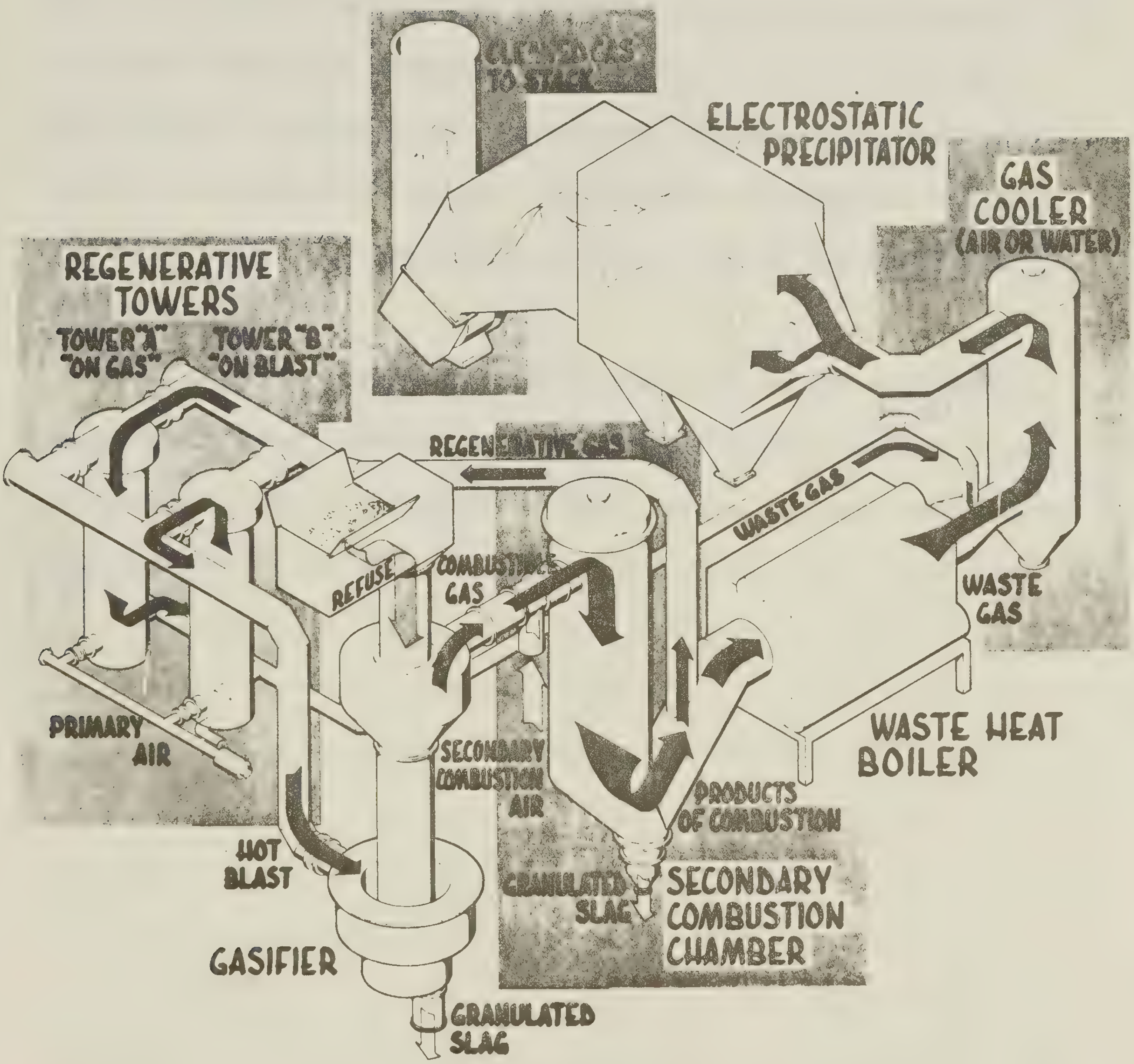


FIGURE 25

SOURCE: GENERAL INFORMATION ON THE ANDCO TORRAX PROCESS

The process involves heating the solid waste in the gasifier to a temperature at which the volatile material will distill, leaving carbonaceous char and inert materials behind. The carbon from the pyrolyzed material is burned to carbon monoxide using high temperature air, releasing enough heat to convert the non-combustibles to molten slag. The molten slag is drained from the bottom of the gasifier to form a black glassy aggregate. The slag represents 3 to 5% of the volume and 15 to 20% of the weight of the original refuse.

The combustible mixture is drawn off to the secondary combustion chamber, and the heat used to generate steam and to heat incoming air. The waste gases are then cleaned in an electrostatic precipitator.

SOURCE SEPARATION

Materials[63] can be recovered from waste for recycling by source separation. Source separation defines the practice of setting aside recyclable waste materials (paper, glass, metal) at the point of generation (home, office, business) by the generator. Materials to be set aside and the categories for separation are determined by the markets in the area for different types of goods. The separation is followed by transportation to a secondary materials dealer or manufacturer. Transportation can be provided by the generator, city collection vehicles, scrap dealers, or recycling organizations.

Source separation is advantageous in that the generator can segregate the recyclable materials before they are contaminated with other materials in the waste stream. Therefore, the goods recycled by this method should be cleaner and more attractive to the secondary materials dealer than the products of any of the other materials recovery processes. Therefore, where there are significant quantities of a given type of material available at a single source and a local market for that material, this method is frequently practiced on those materials. An example of this would be a large retailer who deals with large quantities of corrugated cartons installing a baler to compact the cartons for sale to a local paper dealer.

To expand source separation to the individual household introduces a number of economic problems:

(a) The system is dependent on participation by the householder, who is expected to take the effort to segragate his refuse correctly and store it separately. Different degrees of citizen participation have been encountered in different projects. The Burlington study found that, although people were initially enthusiastic, participation declined throughout the study period.

(b) The handling and collection of the segregated materials is very expensive, due to the small quantities of each material to be recycled from each household. If the segregated materials are collected by the City, the efficiency of collection is decreased. The collector must take the time to place segragated materials in the appropriate compartment of his truck. If one or more compartments are full before he has a full load on his truck, then he must make an extra trip to the unloading point.

(c) If the householder takes his own separated products to collection centers, then the energy expended in carrying small quantities of material by automobile possibly results in a net loss to the system.

Paper is the material most frequently recovered through source separation. Paper is the most common material in the solid waste stream, and there is frequently a ready market for the material.

City of Ottawa Recycling Effort

The City of Ottawa terminated[64] its pilot project in separate collection of sorted metal and glass at the end of February, 1976. Separate collections of paper had ceased in mid 1975, when proceeds from the sale of paper didn't cover the cost of collecting and shipping. The glass recycling met with a participation[65] rate of 43% in one district, but only 15% in a second. The City is continuing to operate two glass-recycling depots in City yards.

The City lost $120 per ton on each of thirty-one tons of glass collected annually in the two districts, for a total loss of $3,720. If that were projected to City-wide collection, the loss would be $205,000 on 1700 tons.

Project Recycle - Calgary

Project Recycle was an anti-pollution and recycling organization[66] which operated in Calgary for three years, closing in mid 1974. The operation, which employed a staff of four to thirty, attempted to economically separate scrap paper, glass, metal and cloth for resale. At the peak of its operation it handled up to fifty tons of solid waste each week.

The operation depended on the householder sorting, preparing and delivering their materials to one of thirty depots. The householders were asked to prepare metal for recycling by cleaning the cans, removing the ends and paper labels, and flattening them. They were also asked to clean jars and bottles and remove any metal

rings or tops.

During the life of the project the organizers received $229,000 in grants from various levels of government, as well as other assistance in the form of low rent warehouse space and loaned refuse containers. They were forced to close when the government grants ran out and they were unable to obtain meaningful support from private business. At one stage of Project Recycle, a pilot project tested the value of separate collections of paper. Projecting their success rate across the entire city they assumed they could pick up approximately 50 to 60 tons per day of paper for recycling. This would amount to approximately 15,000 tons of paper per year from the City of Calgary.

Burlington Waste Reclamation Pilot Study

From July 1971 to January 1972 the Waste Management Branch [67] of the Ontario Ministry of the Environment carried on a Pilot Reclamation Study in Burlington, Ontario. Burlington was chosen for the project because this City had the nucleus of the activity on a volunteer basis and the project had the support of the Town Council. A door-to-door survey prior to the commencement of the collection indicated that 89% of the local residents were willing to separate household wastes for recycling. An area of one thousand dwelling units, containing approximately four thousand people was selected for the separate collections. The area included single family units, townhouses, apartments, a senior citizens area and a commercial area. The citizens of the study area were provided

with instructions on preparation of their refuse and were kept informed of the progress of the operation through news releases, periodic surveys and public meetings. The actual support which was demonstrated during the life of the project ranged from 14.5 to 40%.

The cost benefit analysis of the Burlington Study indicated costs of approximagely $165.00 for a once weekly collection to achieve a gross revenue from the sale of recycled goods of $30.44 per week. Naturally the project was terminated at the conclusion of the study period.

Recycling of Solid Wastes - Victoria, B.C.

In the Capital Regional District of British Columbia a volunteer group, calling themselves Project Recycle, began an operation[68] in February 1971 as a neighborhood recycling group. They were able to obtain Federal Government grants and increase the scale of their activities to cover the entire peninsula around the City of Victoria. They were dependent on householder separations and delivery to neighborhood depots and were collecting approximately 50 tons per month of newspaper, glass and metal which they were reselling. Their report in June 1974 indicated that the project could break even if subsidized at the rate of $3,000 to $4,000 per month.

Since that time, the operation has been taken over[69] as a section of the solid wastes operation of the Capital Regional District staffed by three to four employees of the District. The expenditure budget for 1977 is $93,300, with revenue from the sale of recycled

goods estimated to offset $58,600 of that amount. In 1977 they expect to recycle 1470 tons of paper, bottles, glass cullet and ferrous metals, at a net cost of approximately $24 per ton. The District is operating one main depot and 3 sub-depots.

The District currently has a resource recovery study underway, to determine the relative economics of a 600 tons per day plant utilizing either gasification, pyrolysis, or steam generation technology. Current landfill disposal costs are approximately $2.50 per ton on 3,000 tons per week, not including amortization of land.

Province of Alberta Beverage Container Program

The Beverage Container Act of the Province of Alberta[70] came into force on January 1, 1972. The Act required that all containers used for carbonated beverages be returnable for a deposit. The Act was amended on January 1, 1973 to include liquor and wine bottles, but not beer bottles. Beer bottles were deemed to be effectively recycled through the existing Alberta Brewers Agents, by a system which has operated for many years.

The container depots set up under the scheme purchase the containers back from the consumers for a refund which is set by the Provincial Government. The refillable bottles are returned to the bottlers for re-use. The majority of the non-refillable bottles are crushed and reprocessed in glass manufacturing operations. A small percentage are being landfilled. Approximately 62% (thirty to thirty-five million cans per year) of the metal beverage cans sold in Alberta are returned to the depots. These are virtually all baled for recycling in the steel industry with a small remainder landfilled.

The steel industry is not enthusiastic about receiving significant quantities of baled beverage cans because of contamination problems from aluminum ends and tin plating.

The prime benefit of the Beverage Container Act has been as a means of reducing litter, rather than a viable resource recovery plan. The depots have provided employment for a significant number of Albertans, paid for by the consumer in increased beverage prices. The estimated cost to the consumer in 1974 was $6 million.

Compartmentalized Trucks in Madison, Wisconsin

The City of Madison, Wisconsin uses a "piggyback" system[71] of separate collection for newsprint. The paper collection was instituted in cooperation with the Paper Stock Conservation Committee of the American Paper Institute.

When possible, packer type collection vehicles are equipped with ½ to 1½ cubic yard racks (See Figure 26) beneath the box. Not all trucks can be equipped this way, because of placement of auxiliary gas tanks and hydraulic equipment.

The householder places his bundled newsprint at the curb on collection day, beside the normal refuse cans. The collection crews load the bundled newsprint into the rack and the refuse into the packer, during their normal collection rounds.

The system is restricted by the size of the paper racks. With the 60% participation rate being experienced in Madison, the paper rack fills up two or three times before the packer is full. To minimize lost time, bulk containers are located at strategic

MADISON NEWSPAPER RACK

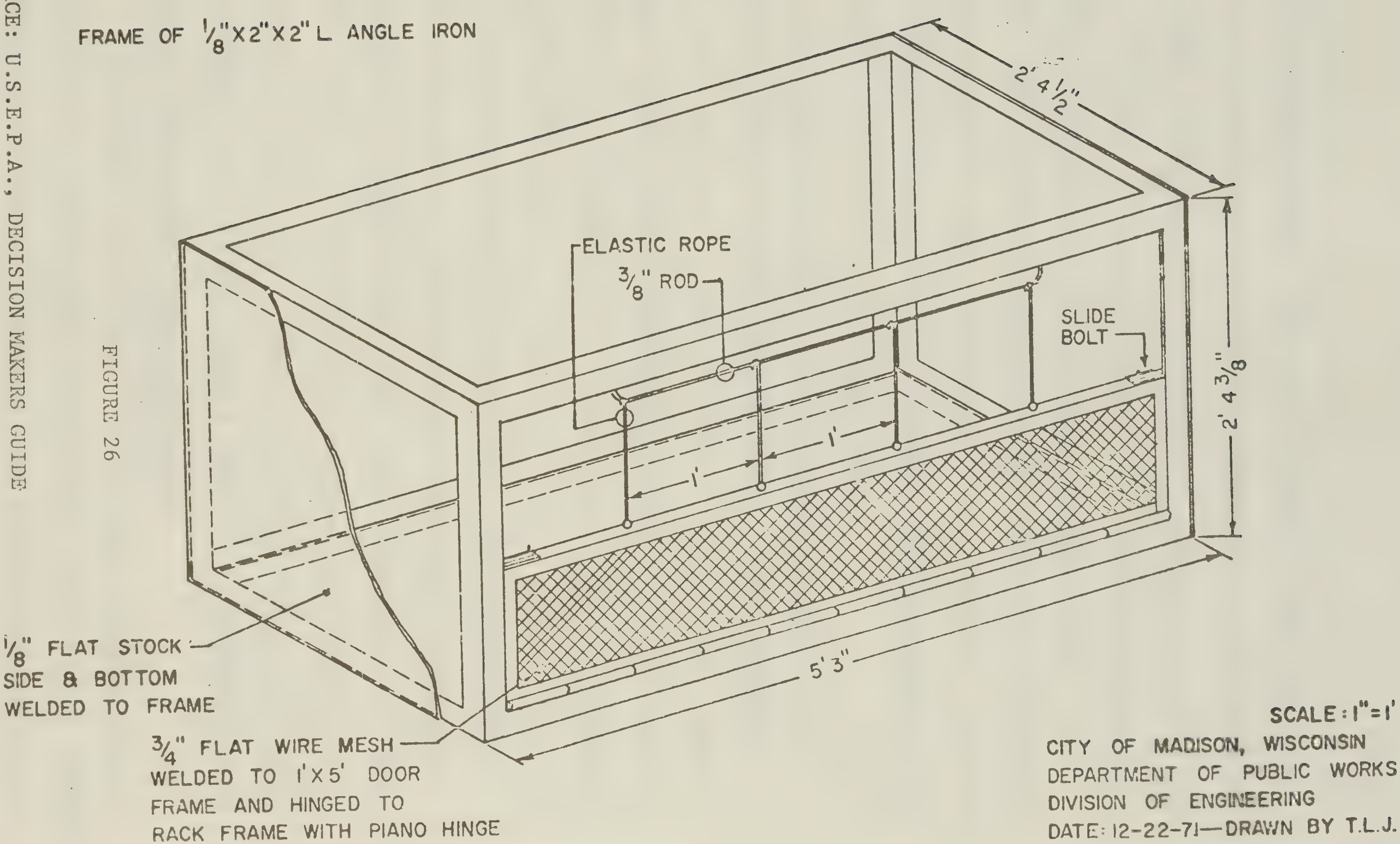


FIGURE 26

SOURCE: U.S.E.P.A., DECISION MAKERS GUIDE

points in collection areas. Each time the rack is full, the crew drives to the nearest bulk container, unloads the paper and returns to the route. An average of ten minutes are lost each time.

Time and motion studies have shown that ten seconds extra crew time are required per stop for separate paper pickup. No additional labour costs have been experienced on collection because the crews had not been fully occupied on normal collection. Servicing of the bulk containers is done by additional staff, requiring one to three man hours per day per collection vehicle.

The paper recycling[72] program in Madison, from a population of 170,000 persons, yielded a gross revenue of $28,617 in 1976 from 2,227 tons of paper collected. The net profit, after allowing for direct costs of handling paper but not for the extra time involved in collection, was $9.60 per ton in 1975 based on the first eleven months data.

Increasing prices for paper in late 1975 and early 1976 resulted in other groups initiating paper collections, reducing the amount available for City collections. From an average of 186 tons per month in 1975, the collections for the first three months of 1976 decreased to 123 tons per month. The net revenue for the same period increased to $19.58 per ton as a result of the higher prices.

University of Alberta Paper Recycling Program

The University of Alberta[73] is currently salvaging approximately 40 tons per month of paper for recycling through local channels. The quantity is increasing, especially since a recent directive from

University management to encourage all staff to participate in the program. It is estimated that 20% of a potential four to five million pounds per year is being salvaged at current rates. This level of activity generated about $10,000 cash income in 1976, plus a reduction of $4,200 to $4,800 in the cost of commercial refuse collection through the use of fewer bulk containers.

For each staff location participating in the program, the University provides a small waste container especially for non-recyclable materials. The larger, conventional waste basket is then dedicated to recyclable paper. Each person then empties their own recyclable basket when full into thirty-five gallon containers scattered at convenient locations throughout the buildings. By packing the paper into the individual baskets, the time between emptying can be stretched to one to two weeks.

A staff member checks the thirty-five gallon hoppers daily, removing those that are full and leaving an empty replacement. The full containers are taken to a central location, where the paper is baled for shipment to the disposal point. The handling process requires the equivalent of two persons full time.

Some committed staff members are pre-sorting the more valuable grades of paper, such as computer cards. This is then collected separately giving a higher yield, up to $0.05 per pound compared to $0.01 per pound for mixed paper.

City of Edmonton Internal Paper Recycling Program

A small section of Management Services Department of the City of Edmonton is operating[74] an expanding paper recycling program within City Hall. In 1976, 71.7 tons were recycled for a gross return of $3,047.09. After collection through an informal system by interested employees and manitorial staff, the paper is palletized and delivered to the disposal point. The operation did slightly better than break even in 1976.

A study of paper recycling in 1973 by Building Maintenance Branch indicated that 1,700 pounds of waste material was collected daily from waste baskets in City buildings in the downtown core, but that paper recycling was not feasible.

METHANE RECOVERY FROM REFUSE

Anaerobic decomposition of organic wastes[75] will generate gas, consisting of about equal quantities of methane and carbon dioxide. This gas has combustion properties very similar to natural gas.

Anaerobic digestion takes place naturally in a landfill, and the gases generated are vented through cracks in the cover material. Construction of buildings and structures on completed landfills[76] must be handled very carefully, to avoid problems resulting from the explosive properties of natural gas. "Mysterious" explosions have been attributed to the construction of buildings over long-since-closed dumps or landfills.

The harnessing of the production of methane gas from landfills is a potential source of relatively inexpensive energy. Some work is being carried out to determine the potential of this energy source, most notably in California.

This methane producing digestion process can be accelerated by using anaerobic digestors to break down the organic wastes. This method breaks down the organic materials as in a landfill, but the process takes hours or days rather than years.

Methane Gas Recovery From Los Angeles County Palos Verdes Landfill

The world's first commercial[77] facility for recovering and purifying methane gas from a sanitary landfill is in operation in California. The purified gas is sold via pipeline to a local

gas utility. The main portion of the landfill was started in 1963 and will be in operation till 1980.

Production of the gas was preceded by a twelve month research and development program on the landfill. Production began in June, 1975 through five wells. The potential capacity of the landfill is expected to be six million cubic feet of methane per day, when fully developed.

The refuse gas is drawn from the landfill through an underground collection system, then treated to remove carbon dioxide, moisture, hydrogen sulfide and other contaminants (See Figure 27)[78]. The clean, dry gas is then pressurized for injection into the utility system.

The landfill and the collection system were designed to fit in with the surrounding residential district. An eighteen hole golf course is under construction on the completed areas of the landfill. The wellheads of the collection system will be covered over with artificial turf to blend into the landscape.

Methane Gas Recovery At Pompano Beach, Florida

Waste Management, Inc., have started construction[79] in 1976 on a gasification plant at their existing shredder facility in Pompano Beach, Florida. Total cost is estimated at $2.5 million.

The plant, still of an experimental nature, is funded by a U.S. Federal Agency. It will process up to 100 tons per day of municipal waste through an accelerated bacterial digestion and fermentation process. The gas produced will not be of commercial

THE NUFUEL PROCESS

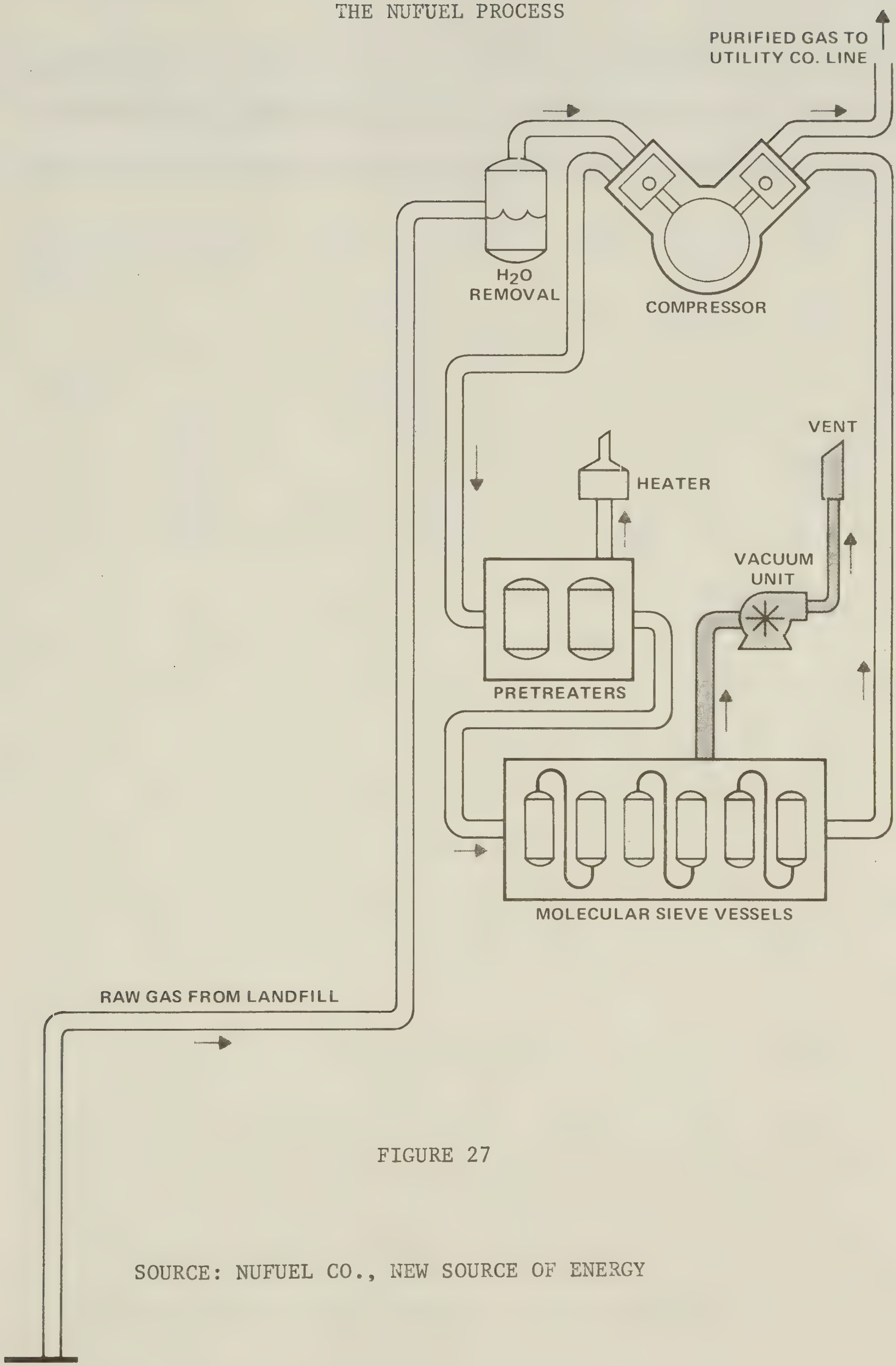


FIGURE 27

SOURCE: NUFUEL CO., NEW SOURCE OF ENERGY

quality. The information gathered from this pilot plant will be used to determine the feasibility of future developments of this type. Purification equipment could be installed later at this plant.

COMPOSTING

Composting[80] is the name given to the bacterial fermentation of organic materials of a cellulosic nature in the presence of oxygen. The decomposition produces a humus like material, which has some value as a soil-builder.

Composting of municipal solid waste has been practiced[81] in Europe and to a lesser extend in North America, for many years. A typical flow sheet for a composting operation is shown in Figure 28. The produce can be withdrawn from the process at one of several different points, depending on the desired end use. The technology of composting is well developed, and there are no real barriers to producing a satisfactory product.

Composting is widely practiced in Europe. In 1972 there were fifty-two plants, each treating about 200 tons per day of refuse, using the Dano process alone. This was the most popular of several processes employed there. The composted product was primarily being used as a soil builder, either in combination with or replacing manure, or as a bedding material for chickens or pigs.

Table 5 shows the status in 1972 of seventeen composting operations which had been opened in North America since the Second World War. By 1976, only the Altoona, Pennsylvania plant was still operating on a regular basis. The major problem for the plants was the lack of a viable market for the compost. Farmers in North America generally find that they can increase crop yields more

GENERAL FLOWSHEET FOR A COMPOSTING OPERATION

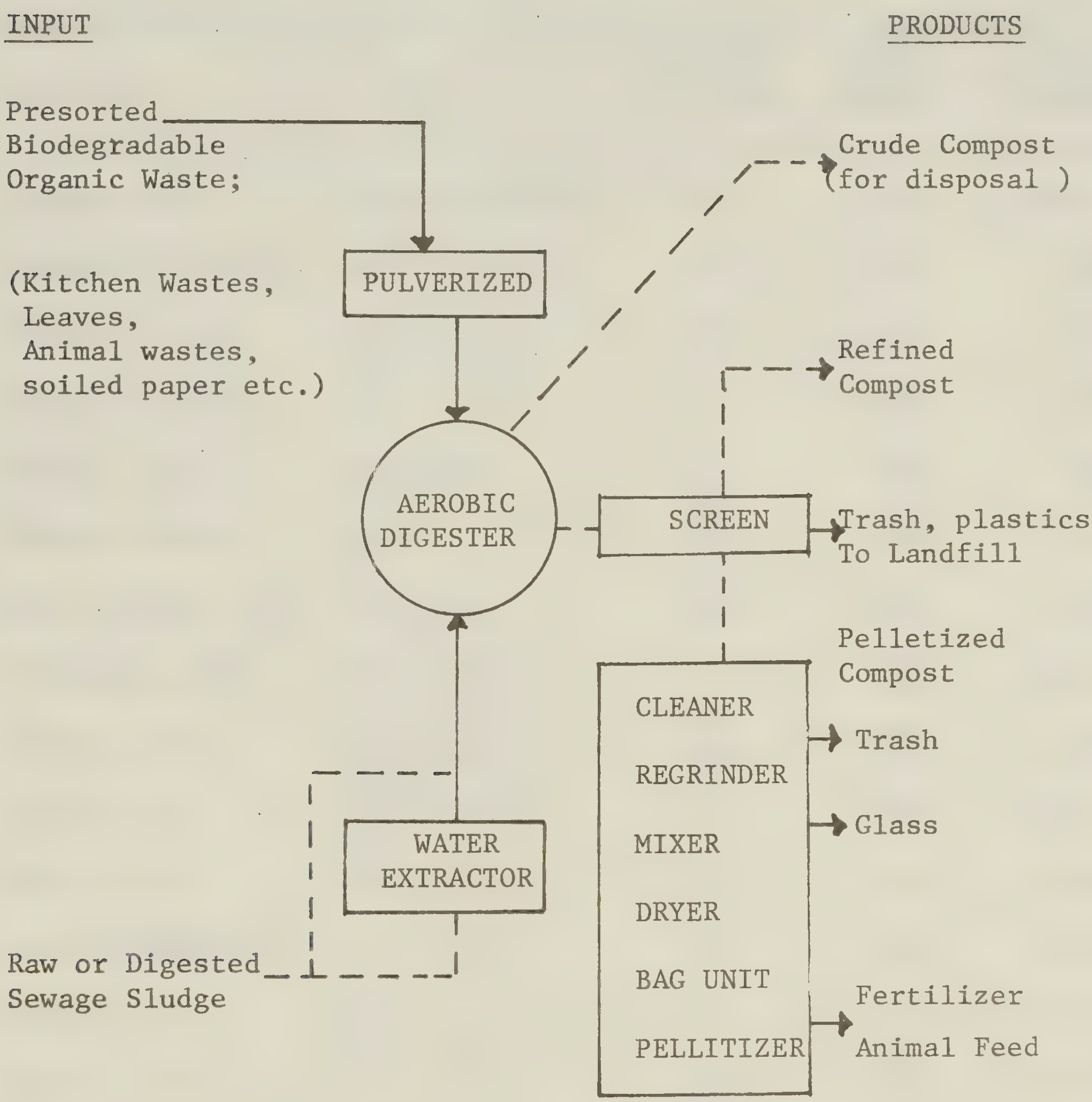


FIGURE 28

SOURCE: SOLID WASTE MANAGEMENT PROBLEMS AND PERSPECTIVES

TABLE 5

STATUS AND TYPE OF U.S. COMPOSTING PLANTS

LOCATION	TYPE	CAPACITY TONS/DAY	YEAR OPENED	YEAR CLOSED
Altoona, Pa.	Fairfield-Hardy	25	1951	Operating
Springfield, Mass	Fraser Ericson	20	1954	1962
McKeesport, Pa.	Open Windrows	100	1956	1957
Sacramento, Cal.	Dano	40	1956	1963
Norman, Okla.	Naturizer	40	1959	1964
Phoenix, Ariz.	Dano	300	1962	1965
San Fernando, Cal.	Naturizer	70	1963	1964
Wilmington, Ohio	Open Windrows	20	1963	Operating
Boulder, Col.	Open Windrows	100	1965	1968
Elmira, N.Y.	Open Windrows	70	1965	Operating
Largo, Cal.	Metro Waste	50	1966	1968
St. Petersburg, Fla	Naturizer	100	1966	1968
Mobile, Ala.	Open Windrows	300	1966	Not Known
Houston, Texas	Metro Waste	300	1966	Operating
Johnson City	Windrows	60	1967	Operating
Gainesville, Fla.	Metro Waste	150	1968	Operating
Puerto Rico	Fairfield-Hardy	300	1970	Operating

SOURCE: SOLID WASTES MANAGEMENT

economically with fertilizer than with compost. As a result, the composted product from the North American operations frequently ended up going into a landfill, rather than into a beneficial use. The average operating cost for North American Plants, not including amortization, was $12.79 per ton.

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CHAPTER III - REVIEW OF ALTERNATIVE RECOVERY SYSTEMS

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CHAPTER IV

MARKET SITUATION FOR COMPONENTS IN EDMONTON

MARKET CONSTRAINTS

Resource recovery is of no value if there is no market for the recovered products. To proceed on a resource recovery project without a thorough knowledge of the local market situation for the products can lead to composting plants producing compost for which there are no consumers, or steam-generating plants unable to operate because no markets can be found for the steam. Therefore, it is essential that, before any resource recovery project is undertaken, a thorough market study be performed.

The laws of supply and demand must be applied in that the process must be designed to supply a product, for which there is a need, at a price which the potential consumer is prepared to pay. There is no point in producing a material from solid wastes if:

(a) There is no local market for the product, or

(b) Transportation costs prohibit shipping to existing markets at a remote location, or

(c) The product will be so impure or so inferior in quality that it cannot compete with alternate sources of supply, or

(d) The cost of preparation of the product for market makes it uneconomical compared to the virgin material, or

(e) Subsidies are necessary to make the recycled product competitive.

In many cases, primary materials enjoy economic advantages over secondary materials because of constraints such as preferential shipping rates, economies of scale, depletion allowances, foreign tax credits, or restrictive purchasing specifications. However, secondary materials will generally possess the advantage of lower energy costs in their production.

In view of the costs of moving secondary materials to market, the sale of recovered materials is generally restricted to the local area. During a relatively short period in 1973, the price of scrap paper was sufficiently high that paper was moving from Edmonton into Japan. However, that lasted for only a few months and has not been repeated. Therefore, it becomes essential to review the local market for recoverable products or energy before any recovery projects are entertained. Then, if there appears to be reasonably attractive and stable, long-term markets for a product of a quality which can be supplied from recovered materials, a comparison should be performed with alternate methods of disposal of the material.

The majority of the processes which have been discussed in an earlier chapter are costing \$5 per ton or more for disposal of refuse, after credits for recovered materials have been deducted from costs. Therefore, if alternate methods of disposal cost less than \$5 per ton, resource recovery would not be justified in those cases. The majority of the projects discussed are in congested urban areas where land is at a premium and landfill sites are

expensive and difficult to obtain. At one of the facilities[1] previously described at San Diego, a cost of $20 per ton for disposal through resource recovery is acceptable because the alternate cost of disposal at distant landfill sites will soon exceed $30 per ton.

The sanitary landfills presently in use by the City of Edmonton are reasonably close to the City, so that hauling costs are not excessive, and costs of landfill are still reasonable. The landfill capacity presently available is expected to last for fifteen to twenty years, and the total landfill[2] cost in 1975 was still less than $2 per ton. Since the majority of the available capacity is presently owned by the City, capital costs will not rise significantly and the only cost escalations will be in the operating component, approximately proportional to the cost of living. In addition to the presently committed locations, further landfill space may soon be available. Negotiations are presently underway with Alberta Environment for the City to fill another location, called the Bretville site, to grades desired by the Provincial Government. Since the final grades have not yet been established, the capacity of the site is not known. However, since the fillable area is approximately thirty acres, it should add at least one to two years to the committed landfill inventory.

Therefore, unless unforeseen circumstances arise which appreciably curtail the life expectancy of existing landfills, the market situation for energy or recycled materials will have to be unusually attractive to justify resource recovery activities.

PAPER MARKETS

One local firm, Paperecycle of Alberta[3], processes the vast majority of paper recycled in the Edmonton area. They collect paper through a system of permanent, as well as portable, paper bins in the Edmonton area, and pick up arrangements in other centres. Presently, they are picking up salvaged paper from points such as Drayton Valley, Red Deer and Camrose, with consideration being given to Fort McMurray. Paperecycle are selling their product primarily to firms in the building supply manufacturing business, such as Cellufibre and Canadian Cellulose (treated paper insulation), Building Products (shingles and building board), and Truroc (gypsum wallboard). The bulk of the paper handled is made up of newspapers, magazines, etc.

Paperecycle project a current demand of 16,800 tons per year in the Edmonton area in 1977. Their market information indicates that this will be a long term situation, with a gradual increase in demand. Present collections through the bins, etc. are yielding approximately 9,600 tons per year, leaving a current shortfall of 7,200 tons per year. The shortfall is being made up by imports of paper by the consuming companies into the Edmonton area.

The one major local newspaper uses approximately 30,000 tons per year of newsprint, of which 18,000 tons are distributed locally, and 12,000 tons outside of the local area. These figures would indicate that, if there were a perfect return on the system, it would be possible to supply the demand from the local area without

the necessity of shipping paper back in from other centres.

Paperecycle are presently collecting through the efforts of private citizens and organizations willing to bundle and collect paper and deliver it to their plant, for a price of $20 per ton, or to their bins and depots in the Edmonton area, for a price of $15 per ton.

To supplement their present system of collections, and test on a small scale the viability of separate collection systems, Paperecycle are trying to organize house-to-house collections in St. Albert or Sherwood Park on a six month trial basis.

To increase the public awareness of the present system of paper recycling, and encourage growth in the amount of paper recycled, the following promotional activities are taking place:

(a) Paperecycle of Alberta, has employed a Waste Paper Consultant, Gay Broderick, to organize their promotional efforts and provide a speaker for service clubs and community groups.

(b) Welcome Wagon hostesses in the Greater Edmonton area are handing out a bulletin (See Figure 29) to new residents to acquaint them with the methods of recycling paper.

(c) The community groups involved in collecting paper advertise the days when the bins will be in their area in their local newspapers and bulletins, and announcements delivered to the homes.

WELCOME WAGON BULLETIN

The purpose of this bulletin is to provide information regarding waste paper salvage for those people who have recently moved into the Edmonton area.

The collection and salvage of old newspapers, magazines, telephone books etc., is entirely dependent upon both the volunteer efforts of the individual citizen and the various community organizations which collect waste newspapers in order to raise operating funds for their activities. There are no government agencies involved in either the collection or the salvage of waste paper in the Edmonton area. It's entirely up to you.

Here's what you can do to help the various organizations with their paper drives:

1. Once a month, separate your waste paper into two piles, newspapers in one, magazines, catalogues, telephone books etc. in the other.

2. Tie the newspapers securely in a bundle using string, twine, wire, old nylons etc.

3. Pack the magazines etc. in a cardboard box or bag.

4. Deliver your sorted waste paper to one of the NEWSPAPER RECYCLING CENTRES listed below:

NEWSPAPER RECYCLING CENTRES

1. MacDougall United Church	101 Street & MacDonald Drive
2. St. Faiths Anglican Church	11725-93 Street
3. Church of Latter Day Saints	9010-85 Street
4. St. Barnabas Anglican Church	15911-107 A Avenue
5. Grace Lutheran Church	99 Avenue & 114 Street
6. St. Mary's Anglican Church	11205-68 Street
7. University of Alberta	Athabasca Hall, U. of A.
8. Church of Latter Day Saints	82 Avenue & 108 Street
9. St. Joseph's Cathedral	10044-113 Street
10. Church of Latter Day Saints	2090 Sherwood Drive, Sherwood Park
11. St. Albert Brownies & Guides	9 Riel Drive, St. Albert
12. Student's Union, St. Francis of Assissi School	6614-129 Avenue

FIGURE 29 (continued next page)

If one of these permanent collection depots is not within a reasonable distance, you may find that one of the rotating paper depots is more convenient. These may be located by checking the Family/Life Style section of the Edmonton Journal on Mondays and Thursdays for the list of NEWSPAPER RECYCLING CENTRE locations.

DISTRIBUTED AS A PUBLIC SERVICE BY WELCOME WAGON

FIGURE 29

SOURCE: PAPERECYCLE OF ALBERTA

(d) The Edmonton Journal carries a listing of Newspaper Recycling Centre locations twice per week in the newspaper.

A study[4] has indicated that, in order for separate collection of paper by City collection personnel to break even, a collection vehicle would have to collect three loads per day of 3,500 pounds each, and deliver them to the salvage depot. Since this is approximately the rate at which normal collections take place, and since paper collections would be considerably more scattered than normal collections, it is unlikely that that rate could be achieved. However, a pilot scale trial of reasonable duration would be required to test that assumption.

Western Canada's largest user of recycled paper, Belkin Packaging are currently increasing their plant capacity in Vancouver[5] from 80,000 tons per year to the range of 150,000 - 160,000 tons per year. The expanded plant will consume paper in the proportions of approximately 10,000 tons newsprint, 10,000 tons mixed paper, 10,000 tons high grade paper, including ledgers and tab cards, to 40,000 tons corrugated boxes. However, the residential waste stream would not be a good source of corrugated paper, due to the relatively small quantities present and the likelihood of contamination by food waste, grass, etc.

Because of the cost of transportation, Belkin's do not find it economical at this time to buy newsprint from as far away as

Edmonton. This, coupled with the unsatisfied demand for newsprint by Paperecycle of Alberta would indicate that export of newsprint out of the local area is currently not of interest.

METAL MARKETS

Analysis of residential solid waste in Edmonton has shown that metal constitutes 5.6% of the stream through the Coronation Transfer Station over a six month sampling period. A U.S. study[6] states that the metal fraction consists of 88% ferrous metal, 8% aluminum and 4% other non-ferrous metal. However, the aluminum fraction is largely made up of the all-aluminum cans. Since the all-aluminum can is essentially absent from Edmonton, the local aluminum content is expected to be closer to 1%, leaving a ferrous component of 5.02% of the water stream.

On an estimated residential waste stream of 150,000 tons in 1976, the ferrous metal component would be approximately 7,530 tons, along with 390 tons of non-ferrous metal. Approximately 40% of this material, or 3012 tons ferrous and 156 tons non-ferrous is processed through a shredding type transfer station, and thus potentially available for salvage. The remainder of the refuse is hauled directly to the landfill by the collection vehicle, making it virtually unavailable for salvage.

The relatively insignificant quantity of non-ferrous metal processed through the shredders, coupled with the fact that the material will be a mixture of different metals requiring different technologies for separation, makes any attempt to recycle non-ferrous metals from the waste stream unattractive unless a total separation process were implemented.

The estimated capacity[7] of the steel-making industry in Alberta and Saskatchewan in 1976 is 750,000 tons per year. The large majority of this material, in excess of 550,000 tons per year, is being supplied by the scrap industry, with the remainder being iron ore pellets. The relatively small quantity of ferrous scrap available from the Edmonton solid waste stream could be readily absorbed into the existing market, without any dislocation of present local markets.

A grant of $25,000 has been received from Alberta Environment, to be matched by $25,000 in City funds, to cover the capital cost of an experimental facility to separate ferrous metal from the refuse at an existing transfer station. It is intended[8] to install magnetic separation equipment in 1977 for pilot plant operation to test the marketability of the product and determine the economics of the process. It is expected that the product will yield from $20 to $35 per ton on the local market, depending on the density of the product and the amount of tramp material present.

A tentative proposal[9] has been received from a market in Wisconsin to purchase the shredded and magnetically and air separated ferrous metal from the 2 transfer stations at a price of $11 to $12 per gross ton, F.O.B. rail cars in Edmonton. The customer is presently buying the ferrous metal scrap from the shredding plant in Madison, Wisconsin, so they are experienced in the handling of solid waste ferrous metal. The proposal suggests a profit to the City of $22,268 per year on this arrangement. However, the

calculations used in arriving at that figure have overlooked the cost of handling of the ferrous metal from its point of separation until its deposit in the rail car, as well as any costs involved in switching and demurrage on rail cars. It is estimated that these combined costs would essentially wipe out the proposed profit.

A one cubic yard sample of shredded ferrous metal was sent to M. & T. Products of Canada Ltd. in Hamilton, Ontario in August, 1976 for evaluation in their de-tinning process. The evaluation[10] indicated that, at the shredder settings which give the optimum shredder performance, the ferrous metal was too tightly balled for satisfactory de-tinning. Adjustment of the shredder to attempt to give a product more suitable for de-tinning would result in less than optimum shredder performance. As well, M. & T. Products do not consider[11] it economic to ship solid waste ferrous metal from as far away as Edmonton for use in their process. They are currently the only de-tinning plant in Canada.

In an agreement[12] of 22 April, 1976 between Alberta Environment and Beak Consultants Limited, Beak were commissioned to perform a $25,000 study of used metal handling and markets in Alberta, and to develop proposals for comprehensive metal management programs. When released, the report should provide considerable insight into the total metal recovery picture in Alberta, and also provide some guidance for the City as to how best to attack solid waste metal recovery.

GLASS MARKETS

The Alberta Liquor Control Board and LB Recycling[13] have surveyed the glass markets available in the Alberta area. LB Recycling are responsible for the handling of all liquor bottles which are returned to the container recycling depots across the Province. Approximately 90% of the liquor bottles being sold in Alberta are coming back into the system via the container recycling depots.

To the limit of the available markets, the glass is being sold by tender from the three warehouses in Alberta at Lethbridge, Edmonton and Calgary. The price varies from $13 to $18 per ton, F.O.B. the warehouse. The two customers are Dominion Glass in Redcliff, Alberta, who manufacture glass container products, and Can-o-Sphere in Moose Jaw, Saskatchewan, who manufacture glass beads for reflecting paints. Flex-o-Lite in Calgary were manufacturing glass beads but have ceased manufacturing in Western Canada.

Approximately 60% of the bottles handled come in through the City depots and 40% through the small town depots. The glass which will be sold is sorted by colour, the caps are removed, and the bottles are broken. Foil labels do not require removal. The glass which will not be sold is broken and taken to landfill.

In the year ending March 1, 1975, 17,000 tons of glass were received by LB Recycling and 6,200 tons were sold, almost all of it to Dominion Glass. In the year ending March 1, 1976, 19,000 tons were received and 8,895 tons sold, approximately 60% to

Dominion Glass and the remainder to Can-o-Sphere.

Inquiries have been made concerning marketing in British Columbia and Manitoba, but transportation costs were found to be prohibitive. Since the existing markets are well supplied by the present system, there appears to be little incentive to consider extraction of glass from solid waste. Window glass and Pyrex glass in solid waste are found[14] to be problems in recycling of glass, since they are of a different composition and can cause hot spots in glass melting furnaces.

PLASTIC MARKETS

Some interest was expressed[15] in early 1974 in the possibility of converting sorted plastic waste into a saleable end product. This interest was expressed during a period of extremely tight plastic resin supply resulting from the world petroleum crisis in 1973 and did not continue.

Plastic scrap of known composition and purity from plastics processing plants is often re-processed at the point of generation or by plastics re-processors. However, even in this closely controlled environment, accidental contamination is very difficult to prevent and processing and quality problems can result. There is no known[16] market in Western Canada at this time for plastic recycled from solid waste.

ENERGY MARKETS

Preliminary financial analyses have been performed by Edmonton Power staff concerning the feasibility of using solid waste, either in the processed[17] or unprocessed[18] form, as a supplementary fuel in the natural gas fired power generating boiler.

The draft reports compared the cost of landfilling all solid waste and burning only natural gas for power generation with the alternative of using a combined fuel consisting of a mixture of natural gas and solid wastes. In each case, the conclusion reached was that the cost of landfilling would have to immediately triple in order to break even on the burning of solid waste as a supplementary fuel in Edmonton. Since the present landfill site has an estimated life of fifteen to twenty years with no major capital expenditures expected, landfilling costs should not escalate significantly faster than the inflation rate. Therefore, it does not appear that there is a viable market for solid waste fuel as an alternative to natural gas in Edmonton.

It is understood that present planning for power generation in Alberta calls for future stations to be fired with coal rather than natural gas. One of the major extra costs in using solid waste to supplement natural gas is for equipment to handle solid fuel and to remove particulate matter from the stack gases. In a coal fired plant, this equipment is necessary for the burning of coal and therefore is not an extra cost when considering the addition of solid

waste fuel. Therefore, if a coal fired power generation plant is built near Edmonton, solid waste might be an economic fuel supplement in that plant. However, if the plant were located any significant distance from the City, the cost of hauling solid waste to the plant might overcome any savings. An economic analysis would be required, once the plant location was determined, to establish the economics of solid waste combustion as a method of volume reduction.

METHANE GAS MARKETS

No experimental work has been done in Edmonton concerning the recovery of methane gas from landfills.

Three landfills have been completed in recent years and turned over to other uses. However, in each case the new use for the site is as parkland, so that experimental work involved in recovery of methane would conflict with the primary use of the site. As well, decomposition of refuse in Northern climates is generally considered to be sufficiently slow that significant quantities of methane gas are unlikely to be released.

The main City of Edmonton landfill at this time is at Clover Bar. It is expected to be used as a landfill for fifteen to twenty years before being converted into parkland. Therefore, it would be feasible to drill wells in that site for determination of methane gas production, if it were considered desirable. However, a far richer source of methane gas exists at the Gold Bar Waste Water Treatment Plant. Up to 500,000 cubic feet per day of 64% methane gas are flared from the plant. When the economics of recovery of this gas were last reviewed in 1973, it was found to be not economic.

However, the price of natural gas, and also the cost of recovery equipment, has escalated considerably since then. It is intended to review the economics of gas recovery at the Water Water Treatment Plant in 1977. Due to the relatively small quantities of gas expected and the remote location of the landfill site, it

would be very unlikely that methane gas recovery would be economic at the landfill before it is economic at the Waste Water Treatment Plant.

FOOTNOTES

CHAPTER IV - MARKET SITUATION FOR COMPONENTS IN EDMONTON

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CHAPTER V

CONCLUSIONS

SUMMARY

The earlier chapters of this thesis have explored the present system of solid waste collection and disposal in Edmonton, the composition of the solid waste, and the resource recovery systems in use elsewhere, primarily in North America. It has been shown that, generally, resource recovery is only being practiced where alternative means of disposal are particularly expensive or where grants from senior governments are subsidizing the operations, or a combination of both. For a strict economic comparison, it would appear that alternative disposal costs must be in the range of $5 per ton in 1975 dollars before full scale resource recovery should be considered. Since the 1975 landfill costs for Edmonton were considerably below $2 per ton, full scale resource recovery does not seem to be viable.

If the life of the available landfill sites were of a short term, then there would be a justification for considering resource recovery as a means of extending that life. However, the presently committed landfill sites have an estimated life in excess of fifteen years. Therefore, there is no immediate urgency for a move into recovery to conserve landfill space.

The review of recovery systems contained in Chapter III has shown that very few are in the mature operational stage of

development. Most are in the planning or construction stage, or in a relatively early period of operation. Start-up problems have been frequent, and early economic forecasts have often turned out to be overly optimistic. The next few years should provide a sorting out period during which some processes will be found to be not economically viable, and the more promising ones will be refined and improved. The state of the technology provides a further reason for not yet moving into full scale resource recovery.

The review of the local market situation has shown that Edmonton is rather far removed from large scale potential markets for recyclable materials. Thus, except for relatively small local markets for some products such as paper and ferrous metals, marketing constraints weigh against materials recovery. In addition, Edmonton is located sufficiently close to major sources of energy that energy prices are relatively low, by North American standards. Therefore, energy recovery from solid waste does not yet appear justified. Current increases in energy prices in Edmonton indicate that this situation may change in the future.

RECOMMENDATIONS

In spite of the relatively negative prognosis for full-scale resource recovery in Edmonton, it must be remembered that landfill space, although presently adequate, is finite. Future available landfill space is liable to be considerably more distant from the City, resulting in higher costs of transportation to the final disposal point. The transfer concept minimizes the impact of the longer haul, but obviously the cost of the solid waste system will increase. Therefore, if landfill space can be conserved by reducing the total waste load without significantly increasing total system costs, the alternative should be explored.

The survey of the recovery systems in use elsewhere, and of the local markets, has indicated that there are some potential economies in the use of landfill space that are worthy of exploration. The recommendations that follow arise from the study of this thesis, and indicate particular aspects of resource recovery that should be studied further. It is possible that, although full scale resource recovery does not appear viable now or in the immediate future, limited projects might result in benefits to the citizens of Edmonton. These benefits could be in the form of extended landfill life, or reduced collection costs, or small financial return from the sale of a commodity. The recommendations are:

(a) That the City of Edmonton embark on a limited

program of institutional type advertising to encourage an awareness in the citizens of the City of the current activities in paper recycling, in order to help increase the amount of paper recycled locally up to an amount closer to the local market.

(b) That the City of Edmonton maintain a working relationship with Paperecycle of Alberta to monitor their success in organizing a pilot scale separate collection of paper in St. Albert or Sherwood Park. That, if they are unable to establish this project there, the City of Edmonton work with Paperecycle to establish a pilot scale operation in a sample area of the City to test the economics of separated paper collections.

(c) That the City of Edmonton Building Maintenance Branch evaluate the economics of an expanded program of paper recycling from City-owned buildings in the downtown core, similar to the program in operation at the University of Alberta. This program should build on the system presently in operation by Management Services Department.

(d) That the City install a magnetic separation unit for recovery of solid waste ferrous metal at an existing shredder installation to evaluate the

market for the metal and test the economics of the process.

(e) That the City consider the wisdom of exploring methane gas recovery at Clover Bar Landfill, after gas recovery at Gold Bar Waste Water Treatment Plant becomes justified.

(f) That the economics of supplemental firing of solid waste fuel be reviewed again, after the location of the next coal fired thermal generating plant has been determined near Edmonton.

LIST OF ABBREVIATIONS

B.T.U./lb., heat content, British Thermal Units Per Pound.

B.T.U. per standard cubic foot, heat content, British Thermal Units per cubic foot of gas at standard temperature and pressure

^{o}C., Temperature, degrees Celsius

F.O.B., free on board

ft^{3}/day, production rate, cubic feet per day

grains/standard cubic foot, contamination, grains per cubic foot of gas at standard temperature and pressure

gross ton, weight, 2240 pounds

hp., horsepower

Kw., Kilowatt, 1000 watts

lbs/hr., production rate, pounds per hour

megawatt, 1,000,000 watts

metric ton, weight, 2204.6 pounds

proximate analysis, analysis of coal giving the relative amounts of moisture, ash, volatile matter, and fixed carbon.

psig., pressure, pounds per square inch gauge

ton, weight, 2000 pounds

ton hour, refrigeration rate, one ton of cooling for one hour

ultimate analysis, analysis of coal giving the relative amounts of ash, sulfur, carbon, hydrogen, nitrogen and oxygen

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